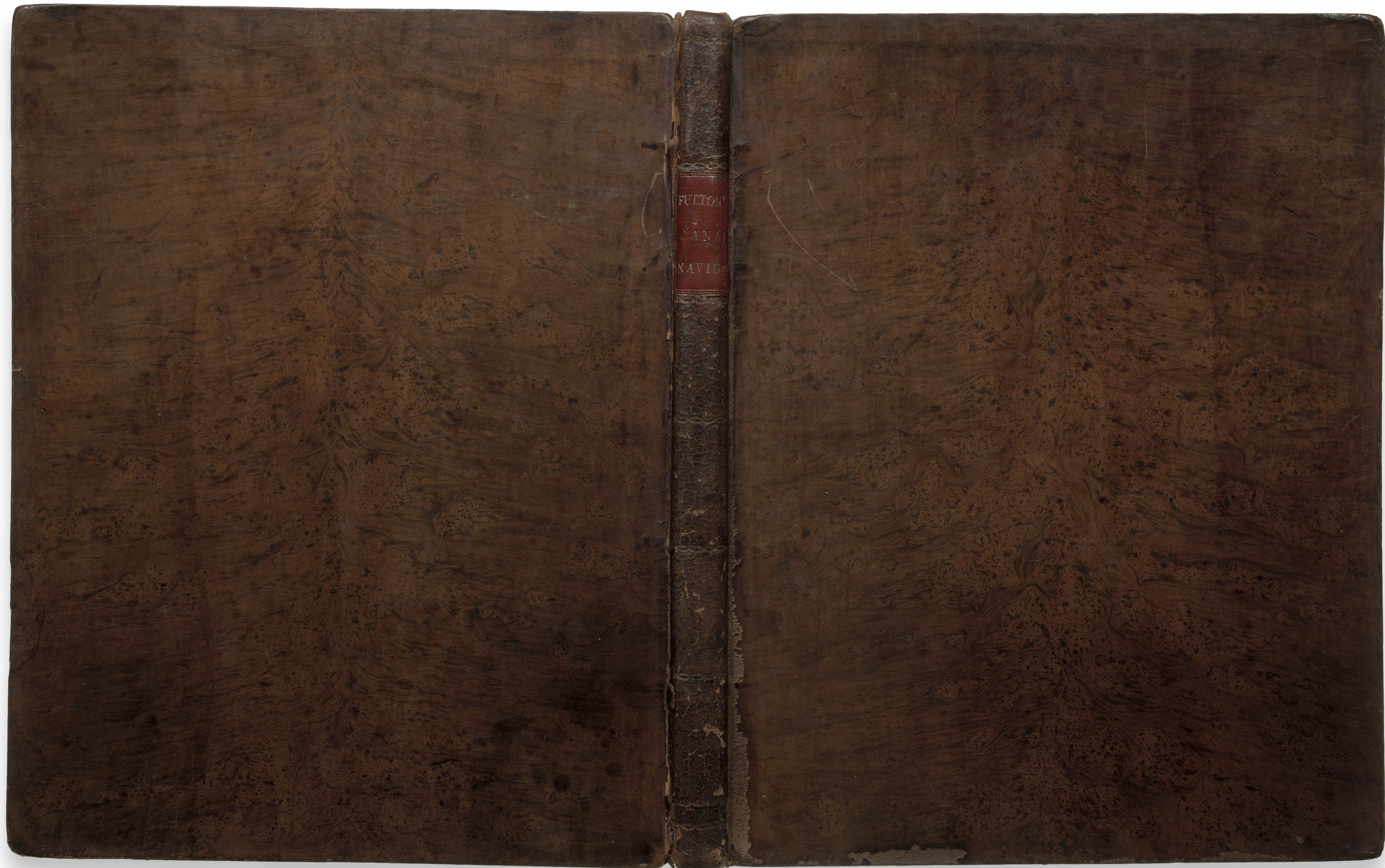




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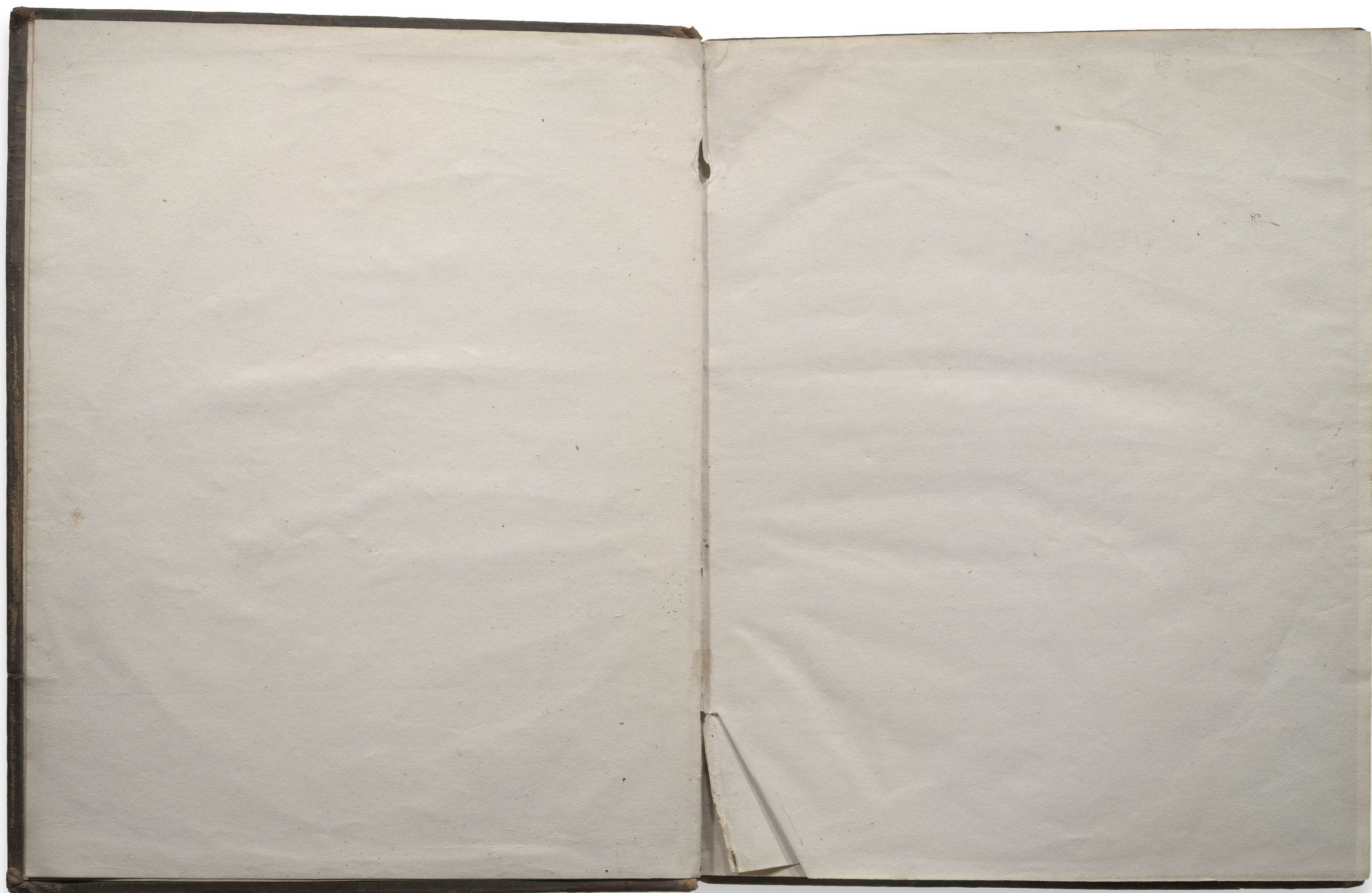
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A
T R E A T I S E
ON THE IMPROVEMENT OF
CANAL NAVIGATION;

EXHIBITING
THE NUMEROUS ADVANTAGES TO BE DERIVED FROM
SMALL CANALS.
AND BOATS OF TWO TO FIVE FEET WIDE, CONTAINING FROM
TWO TO FIVE TONS BURTHEN.

WITH A DESCRIPTION OF THE
MACHINERY for facilitating CONVEYANCE by WATER through the most
Mountainous Countries, independent of Locks and AQUEDUCTS:

INCLUDING
Observations on the great Importance of Water Communications,

WITH
THOUGHTS ON, AND DESIGNS FOR, AQUEDUCTS AND BRIDGES OF IRON AND WOOD.

ILLUSTRATED WITH SEVENTEEN PLATES.

BY R. FULTON, CIVIL ENGINEER.

LONDON.

Published by I. and J. TAYLOR at the ARCHITECTURAL LIBRARY, HIGH HOLBORN.

1796.

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MINUTES of a COMMITTEE of the BOARD of AGRICULTURE, holden
FRIDAY, MARCH 4th, 1796.

THIS Committee having taken into consideration the reference concerning Mr. Fulton's invention, and having examined the Model of his Machines for improving Inland Navigation, by Inclined Planes and various other apparatus, are of opinion:

That the invention is deserving the attention of those who are engaged in the business of forming Inland Navigations.

The above Resolution was afterwards confirmed by the Board of Agriculture, at its meeting on the 8th of March following.

JOHN SINCLAIR, President.

TO THE BOARD OF AGRICULTURE.

MY LORDS AND GENTLEMEN,

WHEN a subject is first brought forward, which has the appearance of novelty, however sound and rational the principle may be on which it rests, yet it is with much difficulty the prejudice in favour of established practice can be removed. The frequent failure of new designs also strengthens the arguments of opposition, and seems to justify those who are disposed to persist in the habits of their ancestors.

On the other side, a warm imagination is the usual companion of those by whom any new plan is formed; hence it becomes necessary

cessary that cool, deliberate, and penetrating men should analyze the ideas, and preserve such as are of intrinsic worth and utility. For this purpose I have a particular pleasure in placing the following pages before the scrutinizing eye of the Board of Agriculture; in which I have no doubt but there are numerous errors, which partiality to a favourite pursuit has prevented me from perceiving: nor have I a wish that any part of this Work should meet with favour, unless it can stand the test of the strictest inquiry, and be supported by reason.

To reduce the expence of canals, and extend the benefit of easy conveyance into every district, whatever natural obstacles may present themselves, is certainly an important consideration; but if I have not been so fortunate as to point out the method, there undoubtedly is one among the infinite materials in the repository of Genius which will be brought into light by energy and investigation. I shall therefore feel happy, should this Work prove a stimulus to induce ingenious men to direct their attention and talents to further improvement.

With the most sincere thanks for the measure which the honourable Board has been pleased to take, in order to bring the subject of small canals to the test of discussion and experience, I remain,

My Lords and Gentlemen,

With the utmost gratitude and respect,

Your obedient and very humble servant,

ROBERT FULTON.

TO

TO MESSRS. JESOP, WHITWORTH, OUTRAM, MILN,
AND RENNIE.

GENTLEMEN,

IN some observations on the utility of small canals, which I printed in the *Star* of July the 30th, 1795, and in which I called on you to state your objections to the system, the Printer, by mistake, having placed the words, *whose merits I esteem*, immediately after Mr. Whitworth's name, instead of inserting it after the names were repeated, it might appear that Messrs. Outram, Miln, and Rennie, were excluded from that respect which I ever feel for men of science. I therefore take this opportunity to explain the error, in order to rectify any bad impression which it might occasion; and I hope this will be deemed a sufficient apology.

At the same time I think it perfectly consonant to the nature of this Work, again to call on you, together with Messrs. Telford, Cockshot, Chapman, and Benet, to deliberately weigh the following pages on small canals, and favour me with your opinion, or transmit it to the public, in order that they may be put in the possession of the arguments for and against the system. In this request I conceive myself perfectly justified: First, Because the improvement of canals is of national importance; second, it is the duty of every man engaged in public works, to investigate every plan which has the appearance of facilitating such works; third, many useful works remain unnoticed, for ages, for want of
immediate

immediate consideration; fourth, by the discussion I propose, the useful or imperfect parts will be more immediately exhibited, and the misapplication of the old mode will be detected: hoping that this system, *to its extent*, will meet the most candid and liberal investigation, and be deliberately considered and compared with the old practice for the various canals in contemplation, or which may hereafter be constructed.

I remain, with all possible respect,

Gentlemen,

Your most obedient,

ROBERT FULTON.

London, March 1, 1796.

PREFACE.

PREFACE.

THE fear of meeting the opposition of envy, or the illiberality of ignorance, is, no doubt, the frequent cause of preventing many ingenious men ushering opinions into the world, which may deviate from the common practice. Hence, for want of energy, the young idea is shackled with timidity, and a useful thought is buried in the impenetrable gloom of eternal oblivion.

But if we consider for a moment, how much men are the sons of habit, we shall find, that almost the whole operations of society are the produce of accident, and a combination of events, rendered familiar by custom, and interwoven into the senses by time; insomuch, that it is mere chance if the ideas are awakened to a sense of particular errors. But in such case it is fortunate, when they arise in a mind active to investigate, and which feels only contented to rest on the basis of reason; for without this, man must ever remain in a fixed point, and improvement will be at an end: the adventurer must therefore arm himself with

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forti-

fortitude to meet the attacks of illiberality and prejudice, determined to yield to nothing but superior reason; resting assured, that every virtuous mind will commend an exertion to remove the rubbish from around the Temple of Truth, even should the undertaking fail.

There is also frequently a secret pride which urges many to conceal their speculative enquiries, rather than meet criticism, or not be thought the first in their favourite pursuit; ever anxious to claim the merit of invention, they cannot brook the idea of having their works dissected, and the minute parts attributed to the genius of other men. But in mechanics, I conceive, we should rather consider them improvements than inventions, unless improvement may be called invention, as the component parts of all new machines may be said to be old; but it is that nice discriminating judgment, which discovers that a particular arrangement will produce a new and desired effect, that stamps the merit. And this may perhaps, with propriety, be called either invention or improvement; which certainly exhibits that the artist has that penetration which is usually dignified with the term Genius. Therefore the mechanic should sit down among levers, screws, wedges, wheels, &c. like a poet among the letters of the alphabet, considering them as the exhibition of his thoughts; in which a new arrangement transmits a new idea to the world.

It

It is for want of this discrimination, that many a worthy man, of easy demeanor, is tormented by the criticism of ignorant insignificance; for men of the least genius are ever the first to depreciate, and the last to commend; and, for an obvious reason, they have not sense to know the produce of genius when they see it: But,

“Men of true genius glow with lib’ral spirit,
And bind a garland round the bust of merit;
While blockheads, void of wisdom’s grateful light,
Bury distinction in eternal night.”

MOREHEAD.

INTRODUCTION.

ON perusing a paper descriptive of a canal projected by the Earl of Stanhope, in 1793, where many difficulties seem to arise, my thoughts were first awakened to this subject.

The canal was intended for the purpose of conveying sea sand, as a manure, from Bude Haven, in Cornwall, to the high grounds near Houlsworth and Hatherleigh, in Devonshire: on which the difference between the summit and lower levels was upwards of five hundred feet, and water extremely scarce. Thus the disparity in the levels, and scarcity of water, which would require numerous and expensive reservoirs, banished every hope of a canal on the lock principle paying the subscribers.

But to accomplish the work, it was proposed by his Lordship to form the ponds of canal at convenient distances, and unite them by iron rail-roads of a gradual and easy ascent, on which boats of two tons were to be used; such boats navigating to the first rail-road, each was to be suspended between a pair of wheels about six feet diameter, and conveyed by a horse to the next ascending level; then navigate to the succeeding rail-way, proceeding thus till the summit was attained.

In a country with little water, and so great a disparity between the levels, and where coals could not be obtained to work steam-engines, such a plan was certainly a good medium between navigation and cartage; but as the whole trade was to go up the country, I was astonished to find, by calculation, that the horses to perform the estimated four hundred tons per day, would amount to 7,000l. per annum on the rail-roads only.

Seeing these difficulties, and the necessity of an easy communication with hilly countries, I was impressed with the importance of an apparatus, which might transfer boats and their cargoes, to and from the different levels; independent of locks and their demand of water, or rail-roads and their appendage of horses.

To produce such a machine, the first thing that occurred to my imagination, was a water-wheel, to be put in motion by water from the upper level; and, by that means, raise the boat on an inclined plane. But in great ascents, I found the wheel destroy more water than locks; I then thought of a preponderating cistern of water, and was so certain of obtaining the power by that means, that I immediately conceived I had accomplished the machine; and having some communication with his Lordship, *on the practicability of navigating vessels by steam*, I sent him a sketch of my plan: his Lordship, in answer, was pleased to compliment me on the thought; but at the same time informed me, it was the same as described by Mr. Edmund Leech, about sixteen years since. Here, for the first time, I discovered that the idea of a preponderating body of water, was

was by no means new. But, on investigating Mr. Leech's work, I found, that although our ideas of the cistern were nearly similar, yet we were far distant from the point to be attained; each using it on an inclined plane, without any certain mode of getting the boat in and out of the upper canal. I then changed the cistern from the inclined plane, to a perpendicular descent; because, in a perpendicular, the descending body acts with a force equal to its whole weight, *friction excepted*; while, on the plane, its descending force is lost in proportion to the angle; after which, my whole difficulty has been to get the boats in and out of the upper canal, with certainty, ease, and expedition, so as to preserve a regular movement, and avoid much wear on the works.

To effect this, I have tried various experiments, and ultimately determined on the *four* modes described by the annexed Plates, each of which works with great certainty and ease, *varying from double to single machines*; and have at least established the practicability of passing boats to and from the different ponds of canals, independent of locks, rail-roads, or steam-engines.

Having accomplished a mode of passing the disparity of the levels, the next important consideration in reducing the expence of canals, was to cross rivers, or deep and wide valleys, without aqueducts. The following Plates will also exhibit the cheap mode by which this part of the work may be performed; and the reader will judge of the facility with which it may be executed.

These

These points being gained, there is no doubt but much room is left for improvement, and that will be progressive as in all other machines: but the result of my experiments I now lay before the public; where, I hope, they will meet with a candid investigation, and the utility of small canals be deliberately considered.

T R E A T I S E

ON THE IMPROVEMENT OF

CANAL NAVIGATION.

C H A P. I.

OF THE ORIGIN AND PROGRESSIVE IMPROVEMENT OF CANALS.

IN contemplating the infinite operations of Art, and reflecting on their progressive improvement, it is an inexhaustible fund of amusement to trace them back to the time when genius called forth the mental powers of our species, and conducted humanity from the wilds of savage life to the cultivated plains of science and refinement.

Ever anxious to dissipate the cloud which intercepts our view of remote times, we endeavour to discover the origin of the subjects we investigate, and to trace them through their various meandrings; pleased, if we find improvement cheer the way, and industry diffuse her blessings through society.

Such deliberations have a happy tendency, by exhibiting our comparative situation with that of former ages, to teach us the absurdity of presuming on present perfection, or of fixing a boundary to any pursuit; they contribute to obliterate the prejudices resulting from established custom; and to open an unbounded field of the most luxuriant soil, gratefully productive to the hand of cultivation, and richly rewarding the toil of the labourer.

For this purpose, I conceive it will not be uninteresting to take some notice of the infant operation of canals, and of their progress from Eastern to Western climes; in which, we shall find, their importance did not escape the observation of some of the early improvers of society.

From the best historical accounts it appears, that in the Mediterranean sea navigation originated and flourished, that sea being the greatest inlet in the known world, and without tides, consequently seldom excessively agitated; also, containing numerous islands, and shores within sight of each other, it was particularly favourable to the young adventurer. Time, with such advantages, having improved the navigator in knowledge, and the surrounding countries in cultivation, the mind began to seek, in streams of artificial direction, those conveniences it had enjoyed on the watery expanse of nature.

The first enterprize of this kind, of which we have any account, is related by HERODOTUS, of the Cnicians, a people of Caria, in Asia Minor, who designed to cut through the isthmus which joins that peninsula to the continent; but who were so superstitious as to relinquish the undertaking because of an interdiction by an oracle.

It

It was also a favourite project with both the Greeks and Romans, to cut a canal through the Isthmus of Corinth; and open a communication between the Archipelago and the Ionian Sea; to accomplish which, DEMETRIUS, JULIUS CÆSAR, CALIGULA, and NERO, made numerous, but unsuccessful, attempts.

The important junction of the Mediterranean and the Red Sea, by a canal through the Isthmus of Suez, has at various times occupied the attention of several kings of Egypt; PHARAOH NECHO attempted a canal from the Nile to the Red Sea, and 120,000 men perished in the attempt. In this great undertaking, it is also said, that, in after ages, SOLIMAN II. Emperor of the Turks, employed 50,000 men; and that the work was completed under the caliphate of OMAR; but afterwards was so entirely choked up by the shifting sands, and loose soil, as entirely to obliterate their immense labours.

As it has been frequently questioned in Europe, whether such a canal was practicable, in order to open a route to India nearer than that by the Cape of Good Hope, I shall beg leave to quote Mr. VOLNEY, who made it a part of his enquiry during a residence at Cairo and Suez in 1782; and who, having a just sense of the subject, exhibits the impracticability of constructing a permanent canal;—for the following reasons:

“*First*, It is certainly true, that the space which separates the two seas is not more than 18 or 19 ordinary leagues; it is true, also, that this interval is not intersected by mountains; and that from the tops of the terraces at Suez we cannot discover with any telescopes a single obstacle on the naked and barren plain to the North West; it is not, therefore, the difference of levels which

B 2

prevents

prevents the junction*: but, the great difficulty arises from the nature of the corresponding coasts of the Mediterranean and the Red Sea, which are of a low and sandy soil; where the waters form lakes, shoals, and morasses, so that vessels cannot approach within a considerable distance. It will, therefore, be found scarcely possible to dig a permanent canal amid these shifting sands; not to mention that the shores are destitute of harbours, which must be entirely the work of art. The country, besides, has not a drop of fresh water; and to supply the inhabitants it must be brought as far as from the Nile.

"The best, and only, method, therefore of effecting this junction, is, that which has been already successfully practised at different times; which is, by making the river itself the medium of communication, for which the ground is perfectly well calculated; for, Mount *Mokattam* suddenly terminating in the latitude of Cairo, forms only a low, and semicircular, mound, round which is a continued plain, from the banks of the Nile as far as the point of the Red Sea. The ancients, who early understood the advantage to be derived from this situation, adopted the idea of joining the two seas by a canal, connected with the river. STRABO, *lib. 17*, observes, "that this first was executed under SESOSTRIS, who reigned about the time of the Trojan war; and the work was so considerable, as to occasion it to be remarked, that it was a hundred cubits (or 170 feet) wide, and deep enough for large vessels."

This work has been repeatedly choked up, and repeatedly repaired, and so sensible were the ancient Egyptians of the utility of

* The ancients were of opinion, that the Red Sea was *higher* than the level of the Mediterranean; but, admitting this to be the case, it would be a trifling obstacle in the present improved state of mechanics, and knowledge of locks.

canals,

canals, that, according to HERODOTUS, SESOSTRIS caused such numbers to be constructed, that they superseded the use of wheeled carriages, which had been in practice till that time. Those works are now buried beneath the wreck of government; are overwhelmed by drifting sands, and sediment deposited from the inundations of the Nile; inasmuch that no mark of their course is left.

In times more modern, when Europe was but emerging from the gloom of Gothic barbarity, the active genius of CHARLEMAGNE projected a plan of uniting the Rhine and the Danube, by a canal, in order to open a communication between the ocean and the Black Sea; in this immense work he employed numerous armies, but the extreme difficulties he had to encounter, after infinite labour and expence, obliged him to abandon the undertaking.

Thus we see, in various periods of society, the most vigorous exertions to open water communications between distant provinces; which works were ever under the particular guidance of the most eminent characters, and prosecuted by such immense numbers of men that the labour is almost incredible; but as manual labour, unaided by mechanic ingenuity, is utterly inadequate to works of this kind, their various failures must be attributed to their ignorance of the genuine principles of science.

The ancients were totally unacquainted with locks, or any other mode of passing vessels from one level, or pond of canal, to another; they, consequently, would be necessitated to pursue the level of that part on which they commenced, be that level what it might; and this in a mountainous country would lead them into high grounds. It is also probable, they would attempt to navigate such vessels as tra-

versed

versed the ocean; while perforating rocks, or making tunnels for those vessels, would never intrude on their imagination. Such circumstances would consequently defeat every undertaking in an irregular country; it is therefore natural to conclude, that each Egyptian canal must have preserved one level; particularly when we consider, that Lower Egypt (*in which they were formed*) is a flat and uniform country.

But although the Egyptians, Greeks, and Romans, were unacquainted with any mode of passing boats to, and from, different levels of water; there is great reason to believe the Chinese have long been familiar with an apparatus for this purpose. Their machine consists of an inclined plane, and a cradle to receive the boat; beneath the cradle are several rollers acting on gudgeons; into this the boat is floated, which fits it so exactly as to give equal pressure on all its parts; the whole is then raised to the next level, or pond of canal (or let down, as the case may be), by men at a capstan (others say, by a water wheel); but it is probable both modes are practised, according to the abundance, or the scarcity, of water. The imperfect accounts of China, which have reached Europe, leave us much in the dark as to the specific operation; and a European mechanic cannot conceive how the power obtained by a capstan, or any other apparatus where manual exertion is the acting force, can be sufficiently quick to accommodate a considerable trade, without incurring a prodigious expence by the number of men employed; as it would occupy at least thirty men during fifteen minutes, to raise a boat of twenty tons to the height of ten feet; the boat, cradle, and cargo, supposed to equal thirty tons; and a repetition of this operation, for instance, so often as is necessary to mount a boat 200 feet, must not only be tedious but expensive; yet all writers agree as to the magnificence of these canals, and their astonishing length: the canal from Canton to

Pekin

Pekin being 825 miles long, through which an immense trade is conducted. Indeed, so vigilant are the Chinese over these works, that they come under the immediate protection of the executive power, and in the instructions given to governors of provinces, these objects are recommended to their particular care. In conformity to this principle, the opinion which the court forms of their conduct is greatly influenced by the attention which they appear to have paid to this part of their instructions: this branch of the police is, consequently, well attended to; and their canals have the reputation of being infinitely superior to any thing of the kind in Europe. Hence, notwithstanding the great extent of the empire of China, the vast multitude of its inhabitants, and variety of its climate, the consequent productions of all parts are transported to, and from, the different provinces, with such facility as to open a home market sufficient to support extensive manufactures.

Machines, similar to those of the Chinese, have been erected in Flanders, on river navigations, where interrupted by falls, or shoal water; while another mode adopted has been to erect a dam, or wear, across the river below the fall, in which was placed two strong buttresses of stone, with perpendicular grooves; after passing the boat above the buttress, a strong gate was let down the grooves, which stopped the water till it rose to a sufficient height to enable the boat to pass; this apparatus, tedious in the process, profuse of water, and liable to injury from every flood, in all probability gave the first hint of locks. And this ingenious invention opened a new scene in canal navigation, in consequence of the facility of passing to and from the different levels. Since which, numerous important works have been executed in the Netherlands, and in different parts of Europe.

Of

Of these, perhaps, the most considerable is the canal of Languedoc: I mean, most considerable, not only from its length, and national importance; but in consequence of the capacity requisite to the construction of it.

It has in fact been the model for all canals down to the present day; in this work, locks, reservoirs, aqueducts, tunnels, and embankments, are plainly exhibited; and the system which has been pursued fully established. This canal, which opens a communication between the Mediterranean and the Bay of Biscay, is 192 miles long; it commences with a reservoir 4000 paces in circumference; and is furnished with 104 locks, each of 8 feet rise. It was begun (in 1666) and finished under Louis XIV. by FRANCIS RIQUET, in little more than thirteen years; the expence amounting to upwards of thirteen millions of livres; which, at twenty-eight livres the mark of silver, the value of French money in the last century, amounts to upwards of 900,000*l.* sterling. On finishing this great work, the tolls were given to M. RIQUET, as a reward of merit, and an inducement to keep it in repair; and the emoluments have been so important as to produce great estates to different branches of that gentleman's family: while, as a public work, it is unquestionably the noblest monument of the monarch who patronized it.

Nor did these useful works escape the penetrating genius of the Czar PETER during his residence in Holland; who, immediately on his return home, procured engineers, and commenced a canal to open a communication between Moscow and Petersburg. It would be a very extensive undertaking to describe the numerous canals which had been formed in various parts of Europe, previous to their introduction into this island: but though England was the last to encourage

encourage canals, it is now the most active in promoting them; tenacious of established customs, Englishmen are difficult to set in motion, but their senses being awakened to interest they are diligent and persevering.

The first canal in England which deserves notice * was constructed by the Duke of BRIDGEWATER, and has not been completed 30 years; during the process, so unacquainted were the people with the use of canals, and so prejudiced in favour of the old custom of river navigations, that the undertaking was deemed chimerical, and ruin was predicted as the inevitable result of his Grace's labour; here tunnels, aqueducts, reservoirs, and embankments, familiar to foreign nations, struck the astonished Englishman with wonder; the apparent expence surpassed all calculation of an adequate return; particularly with a rival running by its side†: yet it was not long finished when the eyes of the people began to open; the Duke could work on his canal when floods, or dry seasons, interrupted the navigation of the Mersey; this gave a certainty, and punctuality, in the carriage of merchandize, and insured a preference to the canal; the emoluments arising to the Duke were too evident to be mistaken; and perseverance having vanquished prejudice, the fire of speculation was lighted, and canals became the subject of general conversation.

But as local prejudices opposed the Duke's canal, in the first instance, prejudice equally strong as firmly adhered to the principle on which it was constructed; and it was thought impossible to lead one through a country, or to work it to any advantage, unless by

* The Romans made a small cut between the Nyne and Witham, below Peterborough, pursuing one level, without machinery or any display of mechanical ability.

† The river Mersey runs nearly parallel to the Duke's canal, and navigates to and from the same port of Liverpool.

locks, and boats of at least twenty-five tons, till the genius of Mr. WILLIAM REYNOLDS, of Ketley, in Shropshire, stepped from the accustomed path, constructed the first inclined plane, and introduced boats of five tons *. This, like the Duke's canal, was deemed a visionary project, and particularly by his Grace, who was partial to locks; yet this is also introduced into practice, and will in many instances supercede lock canals.

Thus we find the majority of men adhere strongly to established customs; and prejudice the common enemy of every new work. Sensible of the power of such an opponent, I shall seek alliance in the investigation of truth; requesting those who take the trouble to peruse this work, to abide by the testimony of common sense; to consider that, as science is progressive, there is yet room to improve, and that the infinite variety of applications to which science is competent, leaves ample opportunity for suggestions no less advantageous than those which have already stood the test of experiment, and received the sanction of success.

* Mr. REYNOLDS's machine is an ingenious combination of an inclined plane, and locks: two locks being constructed on the top of the plane, for the purpose of getting the boats in, and out of, the upper canal; and, although it is only calculated for a descending trade, such as from collieries, or lime works (*in which cases the loaded boat, descending, raises that which is empty*), yet by its operation small boats have been introduced into practice; and for such introduction every future improver will feel infinitely indebted to Mr. REYNOLDS; however, greatly his engine may be improved in construction or varied in its operation.

CHAP. II.

OF THE IMPORTANCE OF CANAL NAVIGATIONS, AND THE BENEFITS ARISING TO SOCIETY BY EASY COMMUNICATIONS.

ALTHOUGH the numerous canals which have been executed within the last thirty years, have exhibited their utility to such persons as have reflected on the subject, yet I may venture to say, that many see their advantages in a limited view, while more than half the inhabitants of England are totally ignorant of their importance, to every district through which they pass.

Like the government of China, the legislature of every country should be particularly attentive to the reduction of the expence and delays of carriage, and to the formation of easy communications between different and distant provinces; as agriculture and commerce will improve, and happiness spread, in proportion as the facility of conveyance increases.

In the early and limited associations of society, while men were kept asunder by forests, morasses, and inaccessible hills, their knowledge must have been circumscribed; and their conveniences few. The rude implements employed in mechanics and tillage, would occasion much labour in proportion to the produce, and though artificers, either by design or by accident, might greatly facilitate their work by a superior contrivance of instruments, yet the difficulty of intercourse would confine the knowledge of such advantages, and

prevent the improvement extending to others who might equally require it; hence, in different districts, particular expedients might be used in performing the various operations; yet, being practised in a limited circle, each community might remain ignorant of the other's advantage; and this state of things in great measure continues in every country, but particularly between distant nations.

The Chinese, for instance, possess many advantages of which we are ignorant; and they certainly are unacquainted with many of ours: yet, was a free communication between the two countries established, the particular improvements of each, in all probability, would be combined to the benefit of both. But, even under the same government, or in the same province, it is some time before a combination of knowledge can take place; but in proportion as the difficulty of communication is removed, the spirit of enterprize increases, and neighbouring associations begin to mingle, their habits and customs assimilate, each transmits its improvements to the other, and each feels the beneficial effects resulting from the union.

This system of intercourse, and benefit, would continue to extend, as the difficulties which withheld, or obstructed, it were removed; and eventually small societies would become a large and social compact; bringing their various improvements into one common stock: a knowledge of mechanics would spread, and greater comforts would result from less labour.

An active man thus situated, and feeling himself by this means in possession of more than was absolutely necessary for his subsistence, would indulge his natural propensity to barter: each would wish to dispose of the surplus of his particular labour, in order to purchase a portion of the labour of others, which his necessities, or
luxury,

luxury, might require; thus the farmer barter his surplus with the tradesmen; the tradesman his with the farmer; the towns exchange the work of their artisans for that of the country; the country its produce for that of the towns; the carpenter, the smith, the weaver, the taylor, the tanner, the shoemaker, the butcher, the brewer, &c. artisans, and professions of all kinds, have reciprocal demands on each other; for not only the elegancies, but even necessities, of life.

It is indeed curious to reflect how, by the refinement of art, and division of labour, the united exertions of thousands combine to produce those things which familiarity exhibits as trifling, yet absolutely necessary to the comforts of existence.

“Observe,” says ADAM SMITH, “the accommodation of the most common artificer or day-labourer in a civilized and thriving country; and you will perceive that the number of people of whose industry a part, though but a small part, has been employed in procuring him this accommodation, exceeds all computation: the woollen coat, for example, which covers the day-labourer, as coarse and rough as it may appear, is the produce of the joint labour of a great multitude of workmen; the shepherd, the sorter of the wool, the wool-comber or carder, the dyer, the scribbler, the spinner, the weaver, the fuller, the dresser, with many others, must all join their different arts in order to complete even this homely production. How many merchants and carriers, besides, must have been employed in transporting the materials from some of those workmen to others; who often live in a very distant part of the country? How much navigation and commerce in particular; how many ship-builders, sailors, sail-makers, rope-makers, must have been employed in order to bring together the different drugs made use of by the dyer, which often comes from the remotest corners of
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the world? What a variety of labour is necessary in order to produce the tools of the meanest of those workmen? To say nothing of such complicated machines, as the ship of the sailor, the mill of the fuller, or even the loom of the weaver, let us only consider what a variety of labour is requisite in order to form that very simple machine, the shears with which the shepherd clips the wool; the miner, the builder of the furnace for smelting the ore, the feller of the timber, the burner of the charcoal to be made use of in the smelting-house, the forger, the smith, must all be joined in their different arts in order to produce them: were we to examine, in the same manner, all the different parts of his dress, and household furniture, the coarse linen shirt which he wears next his skin, the shoes which covers his feet, the bed he lies on, and all the different parts which compose it, the kitchen grate in which he prepares his victuals, the coals which he makes use of for that purpose, dug from the bowels of the earth, and brought to him perhaps by a long sea and a long land carriage, all the other utensils of his kitchen, all the furniture of his table, the knives, the forks, the earthen or pewter plates, upon which he serves up and divides his victuals, the different hands employed in preparing his bread, and his beer, the glass window which lets in the light, and keeps out the wind and rain, with all the knowledge and art requisite for preparing that beautiful and happy invention, without which the northern parts of the world could scarce have afforded a comfortable habitation, together with the tools of all the different workmen employed in producing these different conveniences; if we examine, I say, all these things, and consider what a variety of labour is employed about each of them, we shall be sensible that, without the assistance and co-operation of many thousands, the very meanest person in a civilized country could not be provided, even according to what we may falsely imagine, the easy and simple manner in which he is commonly accommodated: compared, indeed, with the more extravagant

gant luxury of the great, his accommodation must no doubt appear extremely simple and easy; and yet it may be true, perhaps, that the accommodation of an European Prince does not always so much exceed that of an industrious and frugal peasant, as the accommodation of the latter exceeds that of an African king, the absolute master of the lives and liberties of ten thousand naked savages."

Hence we see conveniences, esteemed the most trivial, are the produce of reciprocity; each has a variety of wants which must be supplied by the labours of others; and for which he gives his labour, or the produce of his labour, which is the same thing, in exchange. An easy communication with foreign nations, or the distant parts of the same country, extends the market, and facilitates the transfer; while the ease of transfer stimulates the active powers to exertion.

Thus an easy communication brings remote parts into nearer alliance, combines the exertions of men, distributes their labours through a variety of channels, and spreads with greater regularity the blessings of life.

Men in commercial intercourse mingling with men, imperceptibly lose their local prejudices, and their customs gradually assimilate; while people remote from each other, and destitute of easy communication, retain those prejudices, injurious to the mass of society.

Easy communications to the different districts of a nation, also renders it more independent of its neighbours, by collecting and bringing forth its internal resources; which circumstance must have greatly

greatly contributed, perhaps have constituted, the entire independence of Egypt, China, and India: it is worthy of observation, that, in these countries, where canals were most in use, they never encouraged foreign commerce; but seem to have arrived at their great opulence by a home trade, circulated through their extensive and numerous navigations; indeed, if agriculture and its dependencies may be considered as the stamina of society, a well directed, and judicious, labour, would easily produce the comforts (*if not the elegancies*) of life: Egypt, though not so extensive as England, in former ages contained many millions of inhabitants, and, as it is before observed, they did not draw their resource from other countries; the produce of agriculture must have been immense, and the principal support of the great body of the people. We are taught to believe, they were so attentive to this, that not an inch of ground was lost; the whole country being like a continued garden. This seems the more probable, when the peculiar advantages of the country are considered.

Egypt is a stripe of land 550 miles in length; and in the greatest width, from *Alexandria* to *Damietta*, not more than 125 miles; from thence it decreases in width till it approaches *Nubia*; where it is confined between two chains of mountains, and contracted to little more than twelve or fifteen miles in breadth: through the whole length, the Nile descends to the Mediterranean Sea; it may therefore be considered as a rich valley well watered. As the country is flat, and of an easy descent from one extremity to the other, it enabled the Egyptians to cut canals from any level they thought proper; and to commence so high as to continue the same level to any determined point; those cuts, which answered the double purpose of reservoirs to retain the waters of the Nile, and of canals to convey

vey the various produce, were so numerous as not only to touch at every town and village, but even at many of the farm houses; added to these extraordinary advantages of water carriage, nature performed a most material work for the farmer, by mingling with the stream the soil of *Abyssinia* and *Nubia*, which being deposited as a sediment, and spread over every field and corner of Egypt, by the overflowings of the Nile, formed a rich and fertilizing manure.

We cannot conceive a more regular distribution of the nutritious particles of earth, than was produced by these inundations; which not only enriched, but meliorated, the soil; hence little more was left for the diligence of the farmer than to sow his grain, and cover it with a harrow; thus the Egyptian obtained an abundant harvest with a moderate degree of labour.

Here it is interesting to take a comparative view of such a level country as Egypt, and one diversified by mountains. The nearer a hilly country can approach, by art, to such an equal distribution of manure as the Nile effected, so much nearer it will be to the perfecting of agriculture, and the enjoyments of life; it is, indeed, curious to consider the infinity of labour which the inundations saved, and which consequently might have been directed to other works; the whole process of collecting, preparing, and depositing the compost on the grounds, was saved to the Egyptian labourer, with numerous other preparations requisite to the agriculture of an irregular country.

But observe the immense number of hands employed in such a country as England; in digging marle, and fossile sand, in quarrying lime-stone, in mining for coal to burn the lime; and, in burning it, remark the engines, kilns, implements, and apparatus,

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requisite to facilitate these operations; from thence the labour necessary in their conveyance to the grounds, the wear of roads, waggons, carts, harness, &c. &c. the wheel-wrights, smiths, and other artificers employed in constant repairs; also, the waggoners, the carters, and, above all, the number of horses employed, each of which consumes the portion of manual labour which would support a human being*; of the whole train of which the Egyptians

* I conceive it a fair calculation, that each horse consumes that produce of manual labour which would subsist an individual; particularly in a populous country, where every field pays rent. If their keep is considered throughout the kingdom, from those heavy animals in broad-wheel waggons, down to the pony, calculating the interest on the purchase, the casualties, provender, attendance, shoeing, wear of harness, &c. &c. it will amount to upwards of 25l. per annum, which is more than is spent on an average by the labouring people, and their children; consequently, if improved conveyance can dispense with the horse, 25l. in produce of manual labour is saved to society, as a fund to other works; which, throughout England, would be many millions per annum, considering that every 40,000 horses amounts to 1,000,000l. per annum in maintenance. But these being rendered useless by improved system, would produce an easy support to 40,000 inhabitants.

It is estimated, that, in the agriculture of England and Wales, one million of horses are employed, and if to these are added the number of mail coach, stage coach, and post chaise horses, with those of country and bye carriers, from collieries, lime-works, iron works, &c. also those for the convenience of individuals, in the environs of manufacturing and other towns, with the great number employed in the heavy and fly waggons, *the principal part of which may be dispensed with*, I conceive the number will be little less than two millions, which will amount to the immense sum of 50,000,000l. per annum in maintenance. If from this number of horses, which may be considered as carriers (*not to mention the immensity of pleasure horses*), one fifth could be dispensed with; the annual saving would be 10,000,000l. a sum equal to the maintenance of 400,000 inhabitants, allowing 25l. to each person, which would consequently permit the labours of 400,000 men to be directed to other improvements.

From some recent calculations presented the Board of Agriculture, it appears, that a farm horse does not consume more than three acres of the fruits of the earth in a year; but a horse kept on the roads eats yearly, in hay and corn, the full produce of five acres; a man at a pound of bread and a pound of meat per day, or in proportion, not quite an acre and a quarter; so that one of these horses eats as much as four men: I consequently have stated the saving by the reduction of horses at a very low computation. Which further exhibits the great importance of diminishing their number.

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were relieved, and, being dispensed with, saved so much nourishment to the people.

Deliberate on these circumstances, and the disparity is certainly great, which loudly calls for the exertion of mental faculties, and the improvement of mechanics. Here art should assemble all her engines to supply the defect of situation; man must open the repositories of nature; mix, with chymic skill, the various ingredients, and strew them on his fields. Nature having distributed her fructifying particles in wild confusion; it is with them as with the cultivation of man, to render them productive, they must be brought into union; and this can only be accomplished by improved conveyance. In this operation, canals may be considered like the looms of the draper or hosier; or those improved machines, which, reducing the labour, yet multiply the produce; and consequently render the necessaries, and conveniences, of life more abundant: by being more abundant they are obtained by every member of society, *within their circulation*, with greater ease; the easy means of procuring the accommodations of life increases the population of a country, and population, creating a greater demand, proceeds to further improvement. Such have been the progressive steps of civilization; and to which there appears no boundary!

CHAP. III.

ON THE FORMATION OF CANALS, AND THE MODE OF EXTENDING THEM INTO EVERY DISTRICT.

HAVING in some degree exhibited the importance of canals, the next consideration is to point out a mode of extending their advantages. In this it must be evident, that they can only be advantageously constructed through such districts, as produce a trade equal to an interest for the money advanced in their formation; and on this point the difficulty of extending canal communications seems to depend: public roads, bridges, harbours, docks, and other works, admit of a variation, and may be constructed great and magnificent, or contracted and cheap, in proportion to the trade, agriculture, or population of the country which they are to accommodate; but, according to the present system* of constructing canals, there is a certain point to which they seem to descend†, and below which they cannot be further contracted. The sum required for their construction therefore must be equal to the forming them of those dimensions; and the trade expected must be sufficient to pay the interest of the sum, or the country remain hopeless of the conveniences of water carriage; unless a canal be executed in the frenzy of speculation, which indeed is sometimes the case; and rather injures than promotes such works; for subscribers being disappointed of the interest with which they had flattered themselves, are deterred from entering

* By this I mean the prevailing system; there are but two canals yet constructed on the inclined plane principle, that of Ketly, and the Shrophshire.

† For navigating twenty-five or twenty ton boats.

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into similar undertakings, though of more rational adventure. The ill success also spreads like a contagion, and sickens the soul of enterprise in others; yet the failure is perhaps not for want of materials to be conveyed by the canal, but in consequence of the expence of getting at such materials.

Had the ordinary engines of conveyance admitted of no diminution below broad-wheel waggons, those waggons would, in every respect, increase the expence of roads, and the carriage of the various materials; and the country could not possibly be so commodiously supplied as by carts, or even cars. Or had that incomparable apparatus, the steam engine, been confined to a two-hundred horse power, the innumerable advantages arising from proportioning its powers down to any degree, which fits it to every situation, could never have been experienced, and the engine itself would be of very little use.

A similar power of proportioning a canal to the particular demand of carriage upon it, in like manner, would be attended with benefits which at present are not even thought of; but canals are the only things, which I can at present recollect, which seem to be fixed to a certain point; in this respect, consequently, they are limited in their extension, imperfect in their principle, and incapable of effectually spreading the blessings of water communications by their present mode of construction; to prove this assertion it is only necessary, for a moment, to consider the operation of a lock.

On viewing the operation of locks, it appears that if they were constructed for small boats, *suppose boats of four tons*, the delay in passing would be so great that an important trade could not be transacted, as it requires almost as much time to pass a small

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as a larger boat; for instance, on a man arriving with six four-ton boats (*equal to what is usually conveyed in a boat of twenty-five tons*) at a lock constructed for small boats, he would be obliged to separate them, and pass them singly; which would be an operation of three minutes at least to each boat, together with the time necessary for uniting them when passed through, say four minutes, amounting in all to twenty-four minutes; a repetition of this operation, to mount only one hundred feet by twelve locks, would be a delay of four hours forty-eight minutes: this would not only be tedious, but create confusion wherever there were a number of boats passing, even if passing the same way. How this would be increased by those moving the contrary way, may easily be conceived. Yet the twenty-five ton boat would move through the first lock in five minutes, at the utmost, and passing through the succeeding eleven locks with the same expedition, would rise to the summit level in one hour: hence the twenty-five ton boat will have an advantage in time of three hours forty-eight minutes. This calculation, I hope, will sufficiently prove the impropriety of constructing locks for small boats; hence small and cheap canals cannot be formed on the lock principle; locks demand large boats, that an important trade may be performed; and large boats are the cause of increasing the expence of all the other parts of the canal; in tunnels, bridges, aqueducts, land, reservoirs, digging, &c. &c. which evidently exclude every district which cannot support these heavy expences, and preclude every hope of giving to agriculture and commerce the full force of so powerful an agent as water conveyance.

But as the true criterion for judging of all improvements, *where the object is to increase the produce of labour*, is the cheapness with which the work may be performed; that mode which will convey the most goods for the least money will consequently be the best, whether by roads, railways, large or small canals, or any other mode. It is therefore

therefore necessary impartially and deliberately to investigate this subject.

FIRST, In proportion as a canal is large the expence on all its parts will increase: tunnels, locks, reservoirs, aqueducts, bridges, land, and digging, are usually allowed to be one third more expence in a canal for forty-ton boats, than in those constructed for boats of twenty-five tons; twenty-five ton boats, also, require a canal of greater dimensions than boats of four tons: in a word, it is evident that the expence of a canal will decrease, in proportion as the boats are reduced; the object therefore is to find the proper medium.

The boat should be of such a size as not to exclude any but unusual articles; for this purpose I conceive a boat of four tons sufficiently large; being twenty feet long, four wide, and two feet ten inches deep; such a boat, being larger than the chest of a wagon, will contain almost every thing but long timber*, one horse conveying ten boats.

Such boats will contain lime, lime-stone, coals, lead, iron ore, grain, flour, iron ware, pottery, and all bodies ponderous and compact, as well as boats of any size whatever; they will contain hogheads, boxes, and bale goods, not exceeding four feet in width, *which are seldom of greater dimensions*; each boat will receive fifteen sacks of hops, cotton, or wool; and although the fifteen sacks will not weigh four tons, yet the same circumstance is attendant on all other boats, it being impossible to give the weight of tonnage

* For timber I have made a provision (see the Description of the double-inclined Plane, and Plate of Parts); planks, and all scantlings under twenty feet, will go into the boats.

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by such materials: yet a horse may take the greater number of boats, in order to make up a weight equal to his strength.

Considering the articles enumerated, and deliberating on the size, and weight, of other commodities, I conceive there are few things excluded; and the question is, Whether a company should expend one hundred thousand pounds instead of fifty thousand? Thereby sinking two thousand five hundred pounds per annum, in order to accommodate the few things which boats of these dimensions cannot contain, when, in all probability, the articles accommodated would not in tonnage produce 100l. per annum.

Thus seeing that most things may be conveyed in small boats, and small boats diminish the expence of canals; the next thing to be considered is how to pass them to, and from, the different levels, or ponds, of which the canals consist. To perform this, see the annexed Plates of Machines. But first give me leave to premise the objects in view:

The *first* object is, to construct such cheap navigations as may extend into districts which produce but a small trade: to perform this, I find it indispensably necessary to reduce the boats to small dimensions.

The *second* object is, as the trade may increase, and become of consequence, it is prudent to provide against such an event, as it will then be necessary to perform an important trade on a small and cheap canal. For this purpose; if we reflect that the boats may be multiplied as the trade increases, and that the canal may be full of such boats from one extremity to the other; consequently the canal, and boats, are adequate to any quantity of trade which the most sanguine imagination can conceive.

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But, the principal consideration is, how to prevent stagnation at the machinery; hence it becomes necessary to construct the apparatus in such a manner that the boats may pass with the greatest possible expedition; and this quick transfer is the more necessary, in consequence of dividing the trade into small portions of four tons, each of which must pass separate. Success in these objects will consequently produce system; for, as the canal, though small, and suited to a small trade, is also adequate to a trade of the first importance, it will be impolitic to form any other than cheap and small navigations; hence the boats of one may navigate the other, wherever canals extend.

A third object is, by forming them cheap, and suited to districts with a small trade, it will be the greatest possible inducement to construct them. The subscriber feeling himself guarded against any material loss, with every advantage which a larger work could give*; these circumstances may justly be expected to extend them through the remote parts of the country, open its numerous resources, and spread the produce in every direction. Whether I have succeeded in these points, the candid reader will determine.

* Locks are attended with a certain and heavy expence, whatever the trade may chance to be.

C H A P. IV.

ON CUTTING CANALS FOR COASTING VESSELS, RIVER, OR FORTY-
TON BOATS, IN ORDER TO SAVE THE TRANSFER OF CARGO
TO BOATS OF SMALLER DIMENSIONS*.

IT has been a prevailing opinion, and many canals have been constructed, and are executing, on the principle, that to form them sufficiently large to receive coasting vessels, river, or forty-ton boats, would produce a considerable advantage, by saving the transfer of cargo to small vessels.

While there was no alternative but forty or twenty-five ton boats, there might be some reason in such a practice, as the difference in constructing the canals for such boats does not appear to be materially great; but, if we estimate a canal for a forty, and then for a four-ton boat, the saving, by adopting the latter, is so important as to render the expence of transfer inconsiderable.

In every situation where a canal is to be formed for forty-ton boats, one-third of the sum necessary for that purpose would pay the expence of a canal for boats of four tons†. Hence, if a com-

* If it should be said, that it is not so much in order to save the transfer of cargo, as to accommodate things which cannot be conveyed in small boats; see the Calculations on such accommodation in the preceding Chapter.

† In these calculations, I take no medium between forty and four-ton boats, for, if the cargo is to be transferred, it should be to the cheapest possible conveyance.

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pany are about to expend 300,000l.* where 100,000l. would answer the purpose, 10,000l. per annum is sunk to save transfer. It must be observed, that in all goods passing inland from the coast, there is only one change of cargo, viz. to the small boat; when the small boat unloads up the country, the expence is the same as if the larger had proceeded to the same point. In all goods passing to the rivers, or coast, one transfer into the large boat, the first reception into the small boat being the same as into the large one. Hence all goods going up the country may be taxed two-pence per ton, the price of transfer, and the same on all goods descending: it must also be considered, that although a canal may be connected with the river, or ocean, the principal part of the trade will not require transfer, being taken up, and deposited, in various places on the passage, without descending to the river, or the ocean.

The trade of a canal must, indeed, have a very material connection with a river, where there is occasion to transfer five hundred tons per day; which, at two-pence per ton, allowing 280 working days, would amount to 1166l. 13s. 4d. per annum; yet, to save this, the principal of 10,000l. per annum is sunk.

* To those unacquainted with canal speculations, 300,000l. may appear a great sum; but the following will give him some idea at the moneys expended in such works, of which the estimates are:

	£.	Miles long.
The Rochdale canal, - - - -	291,900	31½
Ellefmere ditto, - - - -	400,000	57
Kennet and Avon ditto, - - - -	420,000	70
Grand Junction ditto, - - - -	500,000	90
Leeds and Liverpool, - - - -	800,000	129

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By adopting small boats, the clear gain to the company would be 8833l. 6s. 8d. per annum, even provided they paid the expence of transfer; but I conceive this expence will ultimately fall on the freighter, or he must have an admirable alternative, much superior to land-carriage, if the two-pence per ton for transfer can prevent him sending his goods by the canal; and therefore, if the freighter or carrier pays the transfer, the 10,000l. per annum is a clear saving to the company.

This reduces a decision on the question of the adoption of small boats in various situations, to a very simple criterion. Let the interest of the saving made by adopting a small canal, instead of a large one, be compared with the expence of transferring cargoes: keeping this in view, that the expence of transfer will fall on the freighter or carrier, who can have no alternative to relieve him from this mode of conveyance; not even if a large canal ran to the same point. No large canal can rival a small one, for evident reasons. Suppose, for instance, a large and small canal running side by side, the large canal costing 300,000l. (*or, in proportion, three times the expence of the small one*), and the small one 100,000l. *one penny* per ton per mile, to the small canal, would be as good interest as three-pence to the larger work; consequently the small canal company could lower their tonnage, so as to favour the freighter, and render the expence of transfer of no consequence; they would even grow rich, by lowering the tonnage; which would draw the trade from the large canal, and leave it a stagnate and useless pool*.

* I do not hesitate to prognosticate the annihilation of lock-canals, by improved science; in like manner as improvement on machinery renders the old apparatus useless.

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The facility and cheapness of the small canal also invites and encourages connection from every quarter; but the difficulty of conducting large boats through a country precludes, or at least most materially limits, their extension.

Considering these circumstances, I conceive there are few situations which can warrant a canal for large boats; short cuts uniting the arms of rivers, or through a flat country to an adjoining town, where there is no great expence, and much to be gained, the latter may be adviseable.

But, to view internal navigation on the broad scale of national improvement, I conceive the river navigations should be extended as far as convenient; but, the moment the course of the river is left to direct water conveyance towards the interior country, small boats should commence.

In the light of national improvement, the produce of labour is the real wealth of a country; the more the labour will produce, so much more the nation improves. As a man who improves a machine, from spinning one pound of cotton per day, to spin twenty; in the same time, and with the same labour, evidently obtains his comforts with greater ease. It is therefore worthy of remark, that, within little more than three years, the immense sum of 5,300,000l. has been subscribed, in order to pay the expence of constructing the various navigations which have been proposed within that time: this sum, averaged at 5000l. per mile, will execute 1060 miles; yet, to a certainty, 2120 miles might be formed on the small scale for the above sum, adequate, in every part, to the various kinds of trade, and thus give to the nation the advantage of 1060 miles additional water carriage, the benefits of which would certainly be immense.

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Of the canals already cut, or in such forwardness as not to admit of an alteration, I consider them in the same view as rivers; but all future works to be guided by the before-mentioned criterion, of comparing the expence of transferring cargoes, with the interest of the money saved, by adopting the small, instead of large boats.

CHAP.

C H A P. V.

OF THE PARTICULAR CONSTRUCTION OF THE BOATS, AND
THEIR APPLICATION TO VARIOUS SITUATIONS.

HOWEVER novel the formation of the boats may appear, at first sight, I hope to be able to exhibit sufficient reason for the particular mode of constructing them: I therefore beg the accurate attention of the reader to this part of the combination, as on this especially I conceive the whole system of small canals is supported.

I have already assigned reason for the boats being small; I have also hinted at the necessity of their passing speedily over the machinery: I must again repeat, and impress this consideration, that the trade being divided into small portions, will, consequently, create a great number of movements at the machinery; it is therefore indispensably necessary, that such movements should be performed with the greatest possible expedition, in order that an important trade may be transacted.

In deliberating on this part of the operation, I found it would be the means of great loss of time, if the boats were to be placed on any kind of carriage, or cradle, for the purpose of passing the plane; that such carriage or cradle would also prevent one movement on the machinery, which is the great means of expedition*; hence, to prevent loss of time, and that the boats

* The rotatory movement of the leading chains, which shall be particularly described in the first machine.

might

might come prepared to pass the plane, I was necessitated to compose the plane of rollers, or to give wheels to each boat: after weighing these two modes of construction, I ultimately determined on wheels to the boats. Rollers being attended with many seeming difficulties, first, that of forming them in a straight line; secondly, that of keeping them true; thirdly, should any rollers be out of repair, the machinery and trade would be stopped, for so long a time as the repairs continued in hand*. But, if a boat was damaged, that boat only would be retained till repaired, which might quickly be done, in consequence of being light, and easily handled.

Having therefore adopted wheels, I shall endeavour to obviate such objections as seem most natural to arise against this combination of a boat and waggon, after describing their mode of formation. For this purpose, see PLATE I. which represents three modes of constructing boats to convey different articles; either by a slow, or by a quick movement, as particular circumstances may require.

Fig. 1. Exhibits the market, or passage, boat.

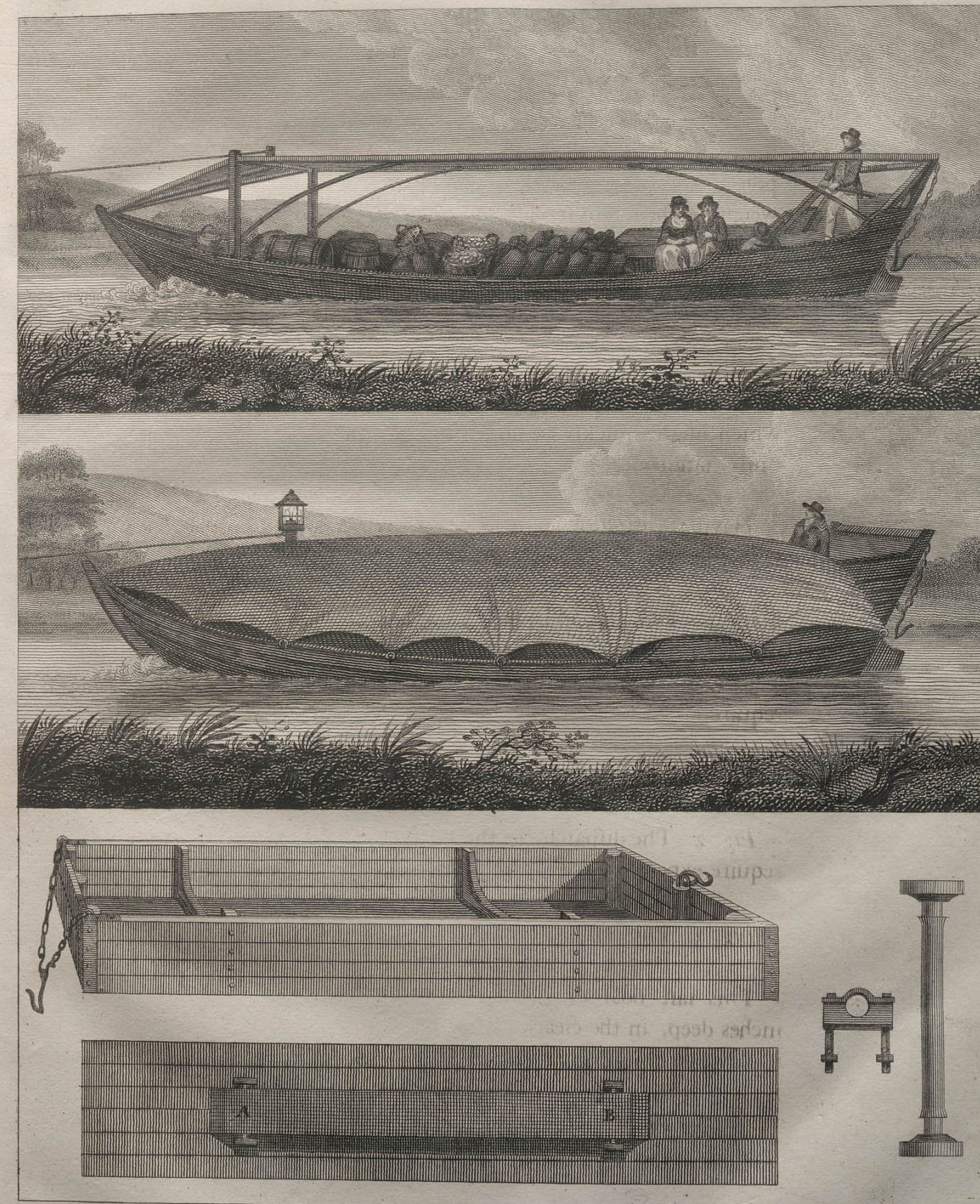
Fig. 2. The dispatch for the purpose of conveying such goods as require expedition.

Fig. 3. The common trader.

This last boat is twenty feet long, four wide, two feet ten inches deep, in the clear; flat at the bottom, and ends like a box; it may be composed of three-inch deal, bolted and screwed in the

* Yet it is possible rollers may be found of use in some cases.

usual



BOATS,

1. The Market or Passage Boat. — 2. The Dispatch Boat.
3. The Common four ton Boat.

London. Published by T. & J. Taylor, Holborn March 13 1796.

usual mode, and stayed at the corners; with two knees, or ribs, inside, exactly above the wheels, and about five feet from the ends, which will leave ten feet in the centre.

Two keels of scantling, about six inches square, and eighteen inches asunder, must be laid along the centre of the bottom to receive the wheels; or if this is not found sufficient, a framing, of the same dimensions as the bottom of the boat, may be constructed to receive the wheels, and on this framing the boat may be built, which will be sufficient to support the weight while she is out of water.

The wheels, which may be from six to ten inches in diameter, are to be two feet distance from the extremities; and may be cast, axle and wheel, in one piece, and turned at the shoulders; or a wrought iron axle if necessary, which axle may move on brass or iron steps.

The wheels being thus small, and short in the axle, will lie close under the bottom of the boat, secure from the possibility of touching the sides of the canal, or receiving injury; the keels, or platform, which compose the bottom, being cased with thin board, will cover every thing but a part of the wheel rim, as represented at A. B. The chains on the end are for the purpose of hooking the boat to the leading chains of the inclined plane. In regard to objections which may be suggested against the formation of this boat, I conceive only THREE can arise.

First, The diameter of the wheels being small may occasion some additional friction, in passing the machinery.

Secondly, The possibility of the wheels being injured.

F

Thirdly,

Thirdly, The resistance on the water, in consequence of the wheels, and shape of the boat.

To the *first* it must be observed, That, while the boat is out of water, it will ever act on a regular plane of cast iron, and never be subject to inequalities, and although the friction will be something more in consequence of the small wheels, yet, as sufficient power may be obtained to raise her, the friction arising from their small diameter will be no considerable impediment.

To the *second*, I conceive the wheels are not subject to receive injury, but while the boat is out of water; and, even then, I do not perceive wherein they are liable to damage; the wear which ensues by a long course of time, only, can affect the boat in this part; and, to this, it must be observed, that she will not undergo so much hardship in passing two hundred miles, as a common waggon in moving one mile on the usual roads.— But, even admitting frequent repairs should be necessary, small slips may be constructed at proper situations, where a man, by a common windlafs, would draw the boat out of water, and repair her, with the same facility as he would remedy a defect in a cart, or a waggon; the process of dry docks necessary to large boats, is by no means required in repairing these.

In the *third* objection, the resistance in the water may appear to arise from two causes; first, from the projection of the wheels in some degree from the bottom; and, second, from the flatness of the boat on the ends. But it must be observed, that boats of this construction are designed to move slow, consequently the resistance arising from the particular construction will be very trifling, and of little importance, resistance being much more

more in proportion to the velocity, than either shape or weight.

To give a general idea of this, it is merely necessary to remark, that should a man attempt to drive a horse sixty miles *per* day, he could scarce convey a boat of the lightest construction at that rate; yet the same horse would convey one hundred tons twelve miles *per* day with ease, and arrive at the end of sixty miles in five days; which is equal to twenty tons *per* day moving through the whole space of sixty miles.

This I hope will be sufficient to shew that resistance from shape, in flow movements, is inconsiderable; also, that the true principle of conveying goods cheap, when expedition is not required, is, to move slow and take a quantity*; and in this respect I shall now consider their superiority over boats of twenty-five tons.

Seeing

* To the reader who may wish to enter more into the abstract, it may be proper to remark, that a body moving in a fluid is resisted from two causes; first, from the cohesion of the parts of the fluid: for a body in motion separating the parts of the fluid wherein it moves must overcome the force with which those parts cohere,

The second cause is, the *inertia*, or inactivity, of matter; whereby a certain force is required to move the particles from their place, in order to suffer the body to pass. When the same body moves through the same fluid with different velocities, the resistance increases, in proportion to the number of particles struck, in an equal time, which number is as the space run through in that time; *i. e.* as the velocity. But further, it increases in proportion to the force with which the body strikes against every part; which force is also as the velocity of the body; and therefore if the velocity be triple, the resistance is triple, from a triple number of parts to be removed. It is also triple from a stroke three times stronger against every particle; therefore the whole resistance is nine-fold, *i. e.* as the square of the velocity; hence a body moving in a fluid is resisted, partly in a ratio to the velocity, and partly in a duplicate ratio of the velocity.

Most authors have considered it as a rule, that while the same body moves in the same medium, it is always resisted in the duplicate proportion of its velocity; that is, if the resisted body move in one-part of its track with *three* times the velocity with which it moved in some

Seeing that the true principle is to move flow and take quantity, in the usual trade, it must be observed that a twenty-five ton boat is a limited quantity, and more cannot with propriety be applied to the horse, consequently he must resort to speed, and combat the resistance.

Two twenty-five ton boats cannot be hooked to each other; as the helm of one will not govern the other, and they are too ponderous to be managed by a boat-hook; they are also so long that, in making the bends in the course of the canal, they separate the fluid by side pressure; the bow of the first separates the fluid, for instance,

other part, then the resistance of the greater velocity will be nine times the resistance of the lesser; and if the velocity in one place be four times the velocity in another, the resistance of the greater will be sixteen times the resistance of the lesser, and so on. See Chambers on Motion.

Hence, as resistance is more in proportion to velocity than weight; if I suppose a boat and cargo to weigh twenty tons moving at the rate of two miles per hour, she will remove a certain number of particles in that time; if the weight is doubled, twice the number of particles will be removed, and the resistance will, in consequence, be double. But, as the speed is not increased, all the resistance which would arise from increased velocity, by the force with which the particles would be struck, is avoided; therefore quantity, to create resistance equal to what speed produces, is nearly as follows: in which I will suppose a horse to convey thirty-six tons at the rate of two miles per hour, and diminish the quantity as the speed is increased.

Miles per hour.	Square of resistance from velocity.	Tons.
2	4	36
3	9	16
4	16	9
5	25	6
6	36	4

Hence, as nine is to four in resistance, so is sixteen to thirty-six in quantity; and so on, in the succeeding numbers, the quantity diminishing as the speed is increased; which determines, that to convey four tons six miles per hour, requires as much power as to convey thirty-six tons two miles in the same time: thus, although the speed is but triple, the quantity is reduced to one ninth part, or as four is to thirty-six—and so on in the other numbers.

to the right, and the stern repels it to the left; the bow of the second boat brings it to the right again, and then the stern drives it to the left; which agitation consequently will retard the motion of both boats: hence, on a canal for twenty-five ton boats, one boat must be the allowance of one horse; he cannot have more; but must endeavour to accomplish quantity by speed, and encounter the consequent resistance.

But of the four-ton boats, ten, fifteen, or twenty, may be linked together, to compose any weight which is thought proper, according to time and distance; being only twenty feet long they incline to the bendings of the canal like the links of a chain, and follow in the wake of each other, being guided by a man walking on the horse-path with a boat-hook; hence, by the system of small boats, a horse may take any quantity, and move with a proportionate velocity.

From boats of this construction, another material advantage arises to proprietors of collieries, lime, delphs, &c.; frequently a canal may pass near such works; and yet it is inconvenient, or inconsistent, with the quantity of trade, to extend the water level to the very spot; which circumstance frequently obliges such proprietors to construct rail-ways, and keep waggons, which they must be at the expence first of loading, before they can deliver the commodity to the boats, and frequently of forming a deposit on the canal banks, from whence they must again load into the boats. But if such works lie above the canal, and not more than six hundred yards distant, so that a regular descent could be obtained; a single road might be formed, and the boat floating on additional wheels might be raised to the pit by the steam-engine employed in pumping, or by the mode described by D. in the Plate of Parts.

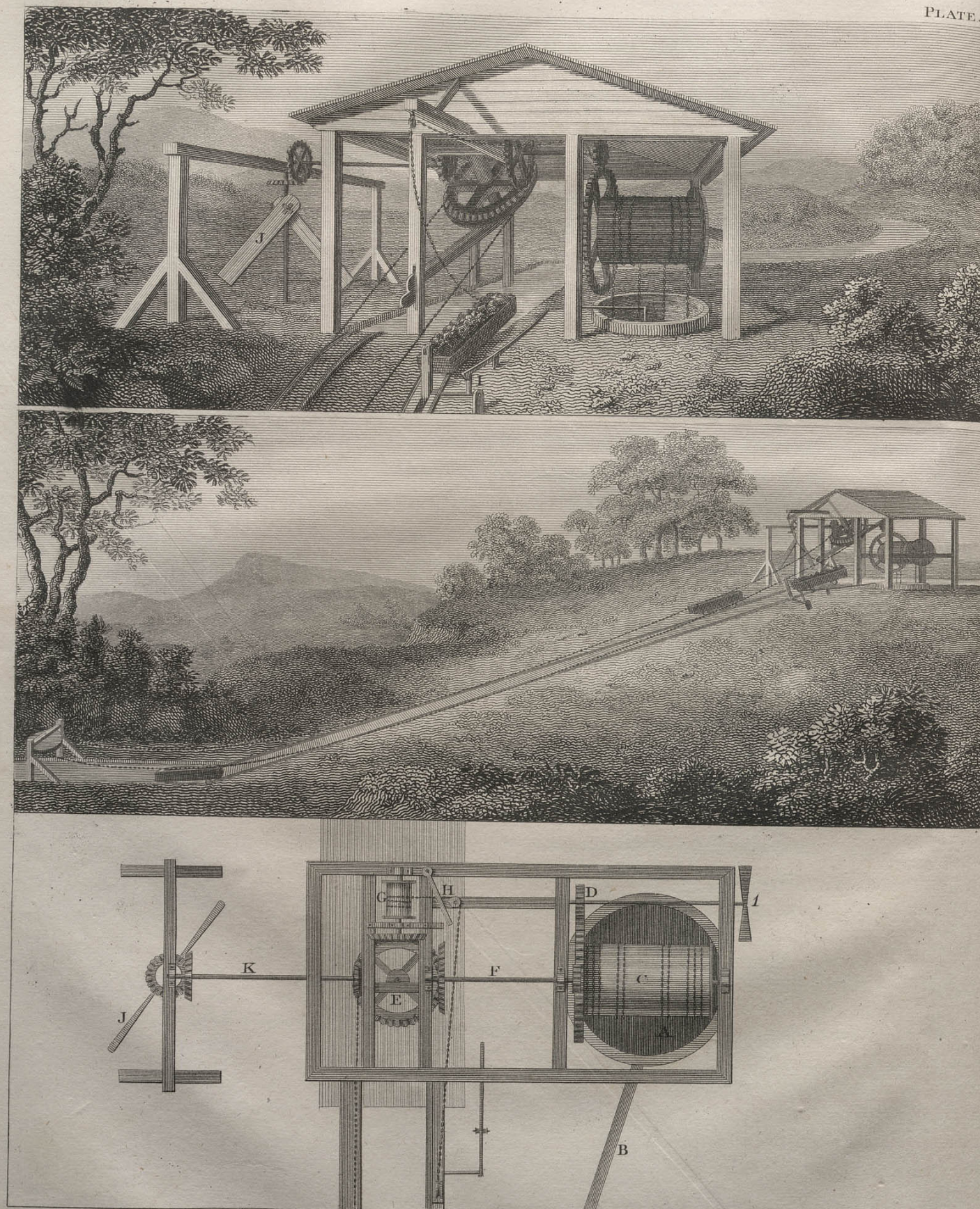
But if such a regular declivity could not be obtained, supposing the ascent was easy, the boat, on a carriage prepared for the pur-

pose, might be conveyed to the works, *any where within a mile*, by a horse; there taking in her cargo, descend from thence to the canal, and be immediately ready for navigation.

It may also be adviseable, in some cases, for the proprietor to reduce his boats to two tons, being twenty feet long, two feet six inches wide, and the same depth; by placing wheels on these boats, of the same dimensions as those of four tons, they will pass the same machinery, and navigate wherever canals so adapted extend; and the advantage to the proprietor would be, that such narrow boats would pass through a tunnel, not more than three feet six inches wide and nine feet high, which may be constructed so cheap as to enable him to drive a water level into the centre of his works *: so far relates to the square ended, slow mover, and common trading boat.

But as various circumstances may require dispatch, such as boats to market, passage boats, or quick communications between trading towns, where valuable merchandize may require speed; Figure the *first* and *second*, represents boats for this purpose, being constructed thirty feet long, four wide, two feet ten inches deep; flat at bottom, with wheels as before mentioned, and sharp at the bow, as speed is required, containing from four to five tons: in building these boats stern posts must be raised about five feet high (as in the Plate), to which the chains are fixed; thus, the chains being raised will prevent the leading chains of the machine from pressing on the goods, or incommoding passengers. Of the operation of these boats I shall treat in Chapter the Seventh, on the System of Navigation.

* I have not been able, *in time for the press*, to procure an exact account of the length of the various tunnels which extend to his Grace the Duke of Bridgewater's collieries at Worsley: but it is said they amount to sixteen miles, which, at 6l. per lineal yard on an average, would cost 168,960l. half of which, 84,480l. might have been saved by employing the two-ton boats.



The Double Inclined Plane.

London: Published by T. & J. Taylor, Holborn March 1796.

CHAP. VI.

DESCRIPTION OF THE SECOND PLATE, EXHIBITING A DOUBLE-INCLINED PLANE, FOR THE PURPOSE OF PASSING BOATS, AND THEIR CARGOES, TO, AND FROM, THE DIFFERENT PONDS, OR LEVELS, IN CANAL NAVIGATION.

As a thorough intelligence of the principles of this machine will give a good introductory idea to the succeeding apparatus, I will endeavour to be particular in the description of it; therefore I hope to be excused if it appear a little tedious, to those who are familiar with some of its component parts; as my wish is to explain the principle to those persons who are totally unacquainted with the subject, which I know by experience to be somewhat difficult; I will therefore first enumerate the parts which compose it.

1st, A double-inclined plane, extending from one pond or level of canal to the other, and running into each canal about sixty feet.

2^d, A pit (or well) in depth equal to the difference between the levels of the two canals.

3^d, A fough from the bottom of the pit, to communicate with the lower canal.

4th, A tub, or cistern, to move in the pit, into which water is drawn from the upper canal in order to create a power to put the machine in motion.

5th,

5th, A trough to convey the water from the upper canal to the tub.

6th, A drum wheel, over the pit, to which the tub is suspended; which wheel gives motion to the remainder of the apparatus; with a small fan to regulate the increased velocity of the tub, in rising from the bottom to the top of the pit.

7th, A weight suspended to the opposite side of the drum; which must be something superior to the empty tub.

8th, Balance chains, which are equal in length to the depth of the pit; these must be fastened, one end to the bottom of the tub, the other to the bottom of the weight.

9th, A horizontal wheel at the bottom of the plane, and over the lower canal; also, a wheel inclined on the same angle as the plane, to be placed at the top; round these two wheels the leading chains are continued, and perform a rotatory movement.

10th, A lying shaft with two wheels multiplied movement, to convey the motion from the drum to the inclined wheel.

11th, A small wheel receiving motion from the back of the inclined wheel; in order to draw the boat out of the upper canal on the bridge of the plane.

12th, A stopper on the plane near the bridge, to prevent the boat descending till the man is ready.

13th, A pair of centrifugal fans to regulate the movement.

14th,

14th, A lying shaft, multiplied movement, to communicate the motion with the fans and inclined wheel.

15th, Building to cover and support the works, with some levers and valves, to be described.

To erect such a machine; the first consideration is, in surveying the proposed line of the canal, to run it to such points of hills as will admit of the greatest possible rise at one time; as this will prevent much machinery and reduce the number of operations.

The slope of the hill must then be formed into a regular plane of any angle under forty-five degrees, to which the ground is best adapted; and extending from one pond to the other, as in Fig. II. Two planes must then be formed, in width two feet one inch, and each distant from the other six feet; the ground work of these planes may be timber, framed together and laid on a bed of rubble, or rough ashlar, or the ashlar covered with coping stones, each of which should be at least three feet long crossing the plane, and not less than one foot diameter, neatly dressed and jointed; this mode would form a permanent plane of stone, the two should be united by wood binders at about every fifteen feet, or cast iron rails would be much better in consequence of their duration. Having formed the plane by either of these modes, the iron rails cast with a flange, and six or more feet long, must be carefully placed two feet one inch apart from flange to flange; if laid on wood, strong spikes will be sufficient security, and if laid on stone they should be carefully bedded, and the spikes or pins fastened by melted lead, observing to fill every aperture to prevent the admission of water, which freezing in winter might split the stone; such a plane of iron and stone is most adviseable as it is most lasting.

G

Of

Of such plane about sixty feet must descend into the lower canal, but of a less angle than the first; it should not exceed four degrees, that by lying flat it may let the boat into the canal without danger of filling. At the part where this last plane joins the first, in entering the lower canal the angle must not be left sharp, but the union formed by a hollow curve, which will let the boat down with a regular motion, without the danger of her bow, or stern, touching either of the planes; which would be the case if the two planes were joined by a sharp angle.

Again, on the summit where the plane turns into the upper canal, the union must be a regular curved bridge, which will prevent the bottom of the boat between the wheels from touching the planes; which would be the case if the planes were united in a sharp point, (comparatively) like the ridge of a house.

Each of those planes, as they proceed into the upper and lower canals, must widen from two to about three feet; or have two rails, placed just above the water, in order with the greater ease to guide the boat to the exact situation; that her wheels may touch in the right part of the plane, and prevent her missing the iron rails.

2dly, Having formed the planes (see the Top Drawing, which represents the Upper Works), A, in the ground plan, exhibits the mouth of the tub pit, and should be sufficiently large to receive a tub which will contain eight tons of water. A tub nine feet diameter and five deep will contain upwards of nine tons, therefore sufficient room for eight without danger of spilling; hence, if the pit is from ten to eleven feet diameter it will be sufficient; which pit may be walled with brick, or stone, as most convenient, like a common coal-pit shaft or well.

3dly,

3dly, From the bottom of the pit a sough, B, to the lower canal, which needs not be more than three or four feet diameter; in fact, as small and cheap as the nature of the measures will admit; as it is of no other use than to let off the water discharged from the tub in the pit.

4thly, A tub must be formed, as before mentioned, capable of containing eight tons of water, nine feet diameter, five deep; this may be made of wood, or sheet iron, like the boiler of a steam engine, and having in the bottom a hole from twelve to eighteen inches diameter, across the hole a strong bar of iron, and in a right line with the bar one must be placed across or near the top of the tub; through each of the bars, and exactly in the centre of the tub, there must be a hole to receive a perpendicular bar, something more than one inch diameter; on the last bar a valve is placed, sufficiently large to cover the hole in the tub; and so placed on the perpendicular, that when it is shut the bar will project about eighteen inches below the bottom of the tub: hence the valve will play perpendicularly, being guided by the perpendicular passing through the cross bars of the tub. The use of the eighteen-inch projection below, is in order that, when the tub descends to the bottom of the pit, the bar may strike the bottom of the pit, and rising with the valve by means of the blow, may discharge the water from the tub. See the Figure of the Tub in the Plate of Parts*.

5thly, A trough must be formed, from about three feet below the top water of the upper canal, to the centre of the diameter of the pit, in which a common valve may be placed of twelve or eighteen inches diameter, in order to draw water into the tub.

* There may also be guides, to preserve the tub in a direct perpendicular through the pit.

G 2

6thly,

6thly, C represents the drum-wheel, which should be about half the diameter of the tub, and so placed that one side may come exactly over the centre of the pit. Care must be taken that this wheel be made sufficiently strong to support ten or twelve tons, *which indeed is not so much as the ordinary weight of a considerable water wheel*: its length may be from eight to twelve feet, but if kept short it will have the more strength. On one end of this drum a spur-wheel, D, must be constructed, that the motion may begin to multiply. For it must be observed, that as the plane will be sometimes six, seven, eight, or more times the length of the pit, the boat will have to pass through so much more space than the tub; hence the movements must multiply in proportion. I will, in this, suppose the plane six times as long as the pit is deep, therefore let the spur-wheel on the drum be three times the diameter of the drum, which will multiply the movement three times, leaving three to be made on the other parts of the machine; the drum and spur-wheel being formed, a pinion may work in the spur *, to the shaft of which a pair of fans will regulate the increased velocity of the tub in returning. The drum being fixed, the tub is to be suspended by two or more chains; and on the opposite side a weight something superior to the tub; the use of this weight, is to return the tub to the top of the pit when the water is discharged.

Balance chains, equal in length to the depth of the pit, *and equal in weight to the tub chains, three feet of one, for instance, being just as heavy as three feet of the other*, must be fixed, one end to the bottom of the tub, the other to the bottom of the weight; and thus, as the tub and weight rise and descend alternately, there will ever be the same quantity of chain pendent, which will preserve a balance on the works; but, without this chain, suppose the tub to be situated at bottom, the weight would have to raise not only the tub, but its chain

* See Fig. I. in the Ground Plan;

also; and the tub would have a similar weight to raise when the weight was at bottom; but now whichever is at top has the whole of the balance chain hanging to its bottom, therefore an assistant to raise the opposite chains and prevent them from being a tax on the machine. (See the Balance Chains in the Plate of Parts).

E, a horizontal, or rather inclined wheel, being on an angle with the plane. This wheel should be of such a diameter, that its extremities might come exactly opposite the centre of the two planes, which will be about eight feet, therefore eight feet diameter; about ten inches broad on the sole, and two flanges: to keep the chain on the wheel round the rim, strong pins, or teeth, must be fixed, on which the links of the chain catch promiscuously, to prevent them slipping; the best mode of forming this will be by segments of iron cast with the flanges, and a row of holes in the centre and end of each, and across the segment, at about one inch distant from each other. In fastening the segments to the wood, the screw-heads may be left pointed, and projecting about one inch, which will answer the purpose of catching the links; on the upper part of this wheel, segments of bevil gear must also be screwed, of the same diameter as the wheels. A wheel of the same size and construction, *excepting the bevil gear*, must be placed at the bottom of the plane, and over the lower pond of canal *this must be horizontal*. Round these wheels the leading chains perform a rotatory movement; a stopper being placed on the upper wheel to prevent it turning back. (See the Plate of Parts.)

F, a lying shaft, to convey the power from the drum to the inclined wheel. By this the remainder of the multiplied movement is performed; by a small pinion working in the spur-gear of the drum, and a large bevil working in the bevil of the inclined wheel,

wheel, the pinion end must be made to cast in and out of the drum-gear at pleasure, particularly to let the tub return.

G, is a bevil wheel with a small shaft, receiving motion from the inclined wheel: to the shaft a rope is fixed, and continued round a pulley, to a beam projecting from the front of the building; the use of this is to draw the boat out of the upper canal on the bridge of the plane, by means of the descending boat, or tub, giving motion to the inclined wheel. When the rope is hooked to the boat, a pull will draw a knot, *which answers as a stopper*, home to the lever H, which moving, the lever drops the wheel into gear. When it has raised the boat to a certain point, another knot, drawing the lever H inwards, lifting the wheel out of gear, it remains inactive, although the other parts of the machine are in motion. This mode of raising the boats out of the upper canal, on the bridge of the plane, keeps a constant supply ready to descend*.

I, (*see the Top-works.*) This is to stop the boat, when drawn on the bridge of the plane, from descending till the man is ready. To place this, a space must be made in the plane, between the rails, about five feet long. The stopper may be a frame of wood, projecting about five feet above the plane, and descending beneath it, where it must be framed into a shaft, working on gudgeons, one end of the shaft projecting about three feet from the side of the plane; to the shaft a weight must be suspended by a chain, which weight will raise it to a perpendicular, after the boat has passed; by which it fastens under the end of the lever, and stops the next boat, and so on†. On the upper end of the stopper there

* As a distinction, this rope may be called the Preparer, in consequence of preparing the boats to descend.

† See the Plate of Parts.

must

must be a roller, rather hollow on the face, to ease the chain as it passes.

J, are the centrifugal fans, composed of wood, and hung to a perpendicular shaft, by bosses on the fans, and a gudgeon through the shaft. The object of these is to regulate the movement of the various weights, without the attention of the workmen, which will consequently be a means of saving time; these fans, as the weights are heavy, and increase in velocity, expand, creating resistance by their action on the air, by which they retard the motion; and, although the weight of the boats may vary, they preserve nearly an equal movement, which will render any attention to this part of the operation useless.

K, is a lying shaft with two wheels; one small, working in the inclined wheel, another of a diameter four, or more, times larger than the first, working on the pinion of the fan-shaft, which is to multiply the speed of the fans; they consequently will create greater resistance.

See the Plate of Parts, Fig. I. which represents the boat entering the upper canal, and the mode of separating from the leading chains, in consequence of the form of the hook, which hook is to be made with a pin about four inches long, crossing at a right angle through the head; by this means, so long as the boat-chains are in a diagonal direction, in ascending or descending, the hook will hold fast to the leading chain; but on entering the different ponds, the roller causes the boat-chains to rise in a perpendicular direction, by which the pin presses on the link, and turns out the bill of the hook, leaving the boat at liberty to run into the canal, without stopping the machine for that purpose, which

I

is

is the means of saving much time, the man paying no attention to the unhooking of the boats. It must be evident, that if the machine was stopped to unhook, at top and at bottom, the man would have to pass from one place to another for that purpose, and consequently lose much time, but, by the hooks casting off, the man's whole attention is employed in preparing boats to rise, or descend; hence the machine is capable of being kept in almost constant motion, and the boats rise and descend, in regular succession, with very little interruption; the same mode of casting off being performed both at top and bottom of the plane, taking care that the roller at top is sufficiently within the bridge, that the boat may tend towards the upper canal, previous to the hook separating from the chain.

E, in the Plate of Parts, exhibits the mode of passing long timber, *all twenty-foots being put into the boats*, each plane is prepared with a carriage for this purpose; and the timber being chained in four-ton parcels, or rafts, is floated on the canal, one horse conveying eight, ten, or twelve, such rafts. On arriving at the plane, each, in succession, is to be floated on the carriage, and, being hooked to the leading chain, they will consequently mount or descend the plane, with the same facility as a boat, and, by this means, timber of any length, or dimensions, may be transported by a small canal.

In Russia and America, all timber is rafted in a similar manner, as far as it is possible to convey it by such means: and I see no reason for objecting to such an operation on canals, the mode of passing to and from the different levels being accomplished.

Having

Having described the formation and use of the particular parts of this machine, I will now go through the operation of passing the boats; in which observe, that, in consequence of the chains performing a rotatory movement, the descending boats will ever pass on one plane, and the ascending on the other: hence the boats will rise, or descend, in a regular succession, and in the same order, as they arrive at the plane; nor will the ascending boats ever incommode the descending, or the descending be any obstruction to those that ascend.

First, it will be necessary to go through the operation of a descending trade, such as is frequent from coal-works, lime, delphs, &c. where the loaded boats descending return those that are empty.

In this case, let it be supposed a number of loaded boats are at top, and empty boats at bottom; the man hooks the preparer to a loaded boat in the upper canal, and the man below hooks an empty boat to the leading chains; water is then admitted into the tub, which, giving motion to the whole machine, draws the loaded boat over the bridge, to the stopper, and at the same time raises the empty boat near to the summit of the plane; this done, the preparer is hooked to a second boat; the loaded boat is hooked to the leading chains, and also another empty boat is hooked below. The tub being cast out of gear to relieve the works, the man lets go the stopper; and now the loaded boat, by its descending weight, raises a second on the bridge, draws the first empty boat into the upper canal, and raises a second empty boat into the place quitted by the first; thus a regular rotation of passing is kept up, in a descending trade, without the use of water.

H

to

to any but the first boat; the first prepares the second; the second the third; and so on, to any number of boats.

The same operation, in all its parts, is performed in an ascending or alternate trade; with this addition, that water is drawn into the tub, to create a sufficient power to raise the loaded boats.

It now comes to speak of the expedition produced by this system.

First, It must be evident to every one, particularly those who have seen any similar operation, that if an alternate movement was adopted, and a boat was to come up the same plane where one went down, the boat could not be raised on the bridge of the plane while the other was passing, because it would occupy the situation where the ascending boat must pass; neither could the descending boat draw the ascending into the upper canal, the descending boat losing its power in touching the lower canal; consequently the ascending boat would not pass through more space than the descending, therefore a stop would take place below the bridge of the plane, as is now the case; but it is the descent of the second boat which draws the first over the bridge, into the upper canal, and raises a second boat into the place of the first; this second is also drawn in by the third descending boat, and so on, which is the consequent result of a rotatory movement, which rotatory movement could not be applied if any kind of cradle, or carriage, was used to convey the boat, as such carriage must necessarily rise, and descend, on the same plane, and consequently give an alternate movement. Hence the necessity of wheels to the boats, or of rollers to the plane.

Secondly,

Secondly, The centrifugal fans regulating the movement, and the cast-off hook discharging the boats from the chains, is a great means of saving time, and, in fact, leaves little more for the men to do than hook boats to the chains, in succession, they rising, and descending, in regular rotation, which admits of such extraordinary speed, that two four-ton boats may pass a plane, whose perpendicular is 200 feet, in three minutes, as will appear by the following statement:

	Minutes.
Hooking the preparer to the boat, - - - - -	0 $\frac{1}{2}$
Hooking the boat to the leading chains, - - - - -	0 $\frac{1}{2}$
Drawing water into the tub, if necessary, - - - - -	0 $\frac{1}{2}$
During this the man below has sufficient time to hook his boat.	
Passing the plane, - - - - -	1 $\frac{1}{2}$
	3 0

During the passing of the plane, the man above, having nothing else to do, may be getting his line of boats forward to the situation for the preparer, or pull forward those boats which have ascended; or this might be the work of a boy, at 1s. 6d. per day. Hence 1920 tons may be performed in twelve hours; and, if this is not sufficient, there can be no difficulty in working such a machine by night, changing the sets of men, who might live in the building over the machine; and thus, 3840 tons may be performed in twenty-four hours, at one plane, which, I hope, is adequate to the greatest canal trade which the most sanguine imagination can conceive; particularly when it is considered, that there is no canal yet known, where 1000 tons per day throughout the year passes at one point of the canal: on a canal sixty miles long, for instance, 5000 tons might move on its various parts,

parts, the transfer of which would be divided among several machines; but, so far as I can learn, there is no canal in England where 700 tons per day moves through one point; therefore, considering every circumstance, I conceive a small canal, and machinery, adequate to a trade of the first importance.

A COMPARATIVE VIEW of the EXPENCE of rising 100 FEET, by LOCKS, or INCLINED PLANES, the usual Expence of Locks for twenty-five ton Boats being 70l. per foot, and for forty-ton Boats 100l. which, in the first case, would cost 7000l. and in the second 10,000l.

In this I shall consider the average of situations and circumstances, as to the form of the ground, carriage of materials, &c. the plane on an angle of 20 degrees.

	£.	s.	d.
Removing 4000 cube yards, in forming the slope of the hill, at 5d. per yard,	-	-	82 10 0
To forming the ends of canal, top and bottom,	-	100	0 0
536 cube yards rubble walling, at 5s. per yard,	-	134	0 0
268 yards squared ashlar coping, 18 inches thick, 3 feet long, at 15s. the running yard,	-	201	0 0
536 yards cast-iron rails, 100 cwt. per yard, 15s. per cwt.	-	402	0 0
Bedding the rails in the coping, lead and pins, 2s. per yard,	-	53	12 0
26 cast-iron binders to unite the planes, 200 cwt. each, at 15s. per cwt.	-	39	0 0
Two horizontal wheels, eight feet diameter, six inches on the face,	-	100	0 0
Carried over,	£.	1,112	2 0
6		Brought	

	Brought over,	£. 1,112	2	0
800 feet chain, 2s. per foot,	- - - - -	80	0	0
34 yards tub pit, 11 feet diameter, 4l. 10s. per yard,	153	0	0	
110 yards fough, at 12s. per yard,	- - - - -	66	0	0
One wrought-iron tub,	- - - - -	60	0	0
700 feet of chain to the tub, weight, and balance, 4s. per foot,	- - - - -	140	0	0
Drum-wheel, eight feet long, four diameter, spur-gear, &c.	- - - - -	100	0	0
Two lying shafts, stopper, and centrifugal fans,	- - - - -	150	0	0
Trough to convey the water to the pit,	- - - - -	10	0	0
Sixty rollers to bear the chains off the plane, 5s. each,	15	0	0	
Building to cover the works, and answer as an office,	200	0	0	
		2,086	2	0
Contingencies, 10 per cent.	- - - - -	208	12	0
	Total,	£. 2,294	14	0
Locks for twenty-five ton boats, 100 feet rise,	- - - - -	7,000	0	0
Double plane to the same height,	- - - - -	2,294	14	0
Saving,	- - - - -	£. 4,705	6	0
Locks for forty-ton boats, 100 feet rise,	- - - - -	10,000	0	0
Double plane to the same height,	- - - - -	2,294	14	0
Saving,	- - - - -	£. 7,705	6	0

In case of a trade totally descending, the loaded boats raising those that are empty, the tub, pit, drum-wheel, and all that part of the machine for creating power, may be saved, amounting to 599l. the contingent expences being reduced in proportion; in which case, a double inclined plane, to the height of 100 feet, would cost 1,635l. 16s.

This, compared with the expence of locks for twenty-five ton boats, will be a saving of 5,364l. 4s. and on locks for forty-ton boats 8,364l. 4s.

In this operation, when a number of loaded boats have to pass down during the day, it is only necessary to leave a loaded boat on the bridge of the plane, which will be a power in reserve to begin work in the morning; or, if this is not consistent with the nature of the trade, the first boat may be raised on the bridge, by the man, with a common windlass, tooth, and pinion, which may be a work of about ten minutes; but, that done, it will raise all the remaining boats on the bridge, ready to descend, as before described. Thus the machine may be constructed for an alternate, or a descending trade; which last will frequently be required in lateral cuts, particularly in the lime and coal trade; but, should future extension open an alternate trade, the water-tub, and all the parts for creating power, may be added to the plane, with the same propriety as in the first instance; and this may be done without interrupting the trade one hour.

I now begin to apply the various apparatus to the several directions and portions of trade, in order that the expence may be contracted in proportion as the trade is small, yet enlarged with

with facility as trade varies in direction, or increases in quantity: thus a canal may commence, like a man, on a small capital, and rise to consequence out of its own earnings.

As the machine is reduced in expence, the quantity which it will perform is also contracted: in the descending trade about nine hundred tons will be the work of twelve hours.

CHAP.

CHAP. VII.

OF THE SYSTEM OF NAVIGATING.

AS a plane will rise from fifty to two hundred feet at one time, consequently, the ponds of canal may be longer, without interruption, than on the lock principle; and as men will be stationed at each machine, whose business it must be to pass the boats at so much *per ton* *, I conceive the best mode of navigating will be, when a man arrives with his ten, or more, boats at a plane he should immediately leave them for the men to transfer, and, taking such boats as are ready, return to the source or machine from whence he came.

When the boats have been passed by the engine-men, they are navigated by a man to the next machine, and so on, till the voyage is completed. In a trade of lime-stone, coals, iron-ore, slate, flags, deals, and various other articles, it could not make the least difference, in such materials, if a boat remained a few hours at a plane waiting for transfer; but in case of the arrival of merchandize, it should be passed immediately, leaving the other boats for that purpose.

By this mode the same boatman will not navigate the whole line of canal, but will always work on one pond; which I conceive to

* On the Ketley and Shropshire canals, a five-ton boat is passed at a plane for 3d. the empty boats return *gratis*.

be a convenience: for if I suppose the ponds between the planes from one to ten miles long, it will be easy to calculate the number of trips which a man can perform *per* day, on each respective length, from which his wages may be determined; he will set out without fear of interruption by lock-keepers, or of being delayed by numerous boats meeting at the same lock or locks; and he may ever work in the neighbourhood of his own habitation.

In the course of a voyage a person at a particular place may want to receive four, eight, or more, tons of coals, lime, or other materials, who has no occasion for more; thus one, two, or more boats may be left at the most convenient situation to unload, without detaining the remainder, and the boats so left may be emptied by the purchaser, before the boatman's return: but, in the case of a twenty-five ton boat, the whole must be detained till the quantity purchased is discharged.

This mode of a man always working on the same pond, and in the neighbourhood of his own house, will be productive of boatmen, as any kind of horse will set a poor man up in business; the size of the boats enabling him to take a weight proportioned to the strength of his horse, mule, or even ass. Besides, as the whole object is merely to get them conveyed from one machine to another, he needs but little capacity, as he has nothing to do with machinery. Thus almost any kind of man will do for a boatman, and hence a competition will arise on the different ponds, and competition will not only produce attention, and civility, but also moderate charges.

It now remains to consider, how this system will operate on a home, or extended, trade. As the property will pass through various hands,

hands, or rather come under the care of many, during its passage to any great distance.

To take a general view of this, the practice which most resembles it, is the mode of sending valuable merchandize by the mail or other coaches, for instance, from Scotland to London; which property passes through the hands of various coach proprietors and changes of coaches, yet arrives at the destined spot with certainty: or it resembles the practice of a merchant, who ships goods for the continent; in which case they have first water, and then land carriage, sometimes for many hundred miles: he and his correspondent have their agents established in various parts to facilitate the transit; who being also agents for many others, find it worth their while to pay a proper attention to the goods, and thus the articles safely reach the foreign market to which they are consigned; custom and regularity having rendered the mode familiar and easy.

Interest will also bend men to the various circumstances, if one mode can be proved cheaper than another; it is therefore almost impossible for a mode to be pointed out, which may be precisely followed on these navigations. But I will mention such as I conceive will answer; and this by established agents.

Suppose, for instance, a man of good capacity resides near or in the building over the machinery, where at least he might have a counting-house; this man might be toll-collector to the company, and at the same time agent to the various traders who used the canal; which employment probably would produce a handsome annual profit, and his agency might be performed at so much *per* ton: on a canal, for instance, with a trade of three hundred tons *per* day, allowing two hundred and eighty working days in the year, one

farthing *per* ton would produce him 87l. 10s. *per annum*; which, with toll-collecting, might amount to upwards of 100l. a sum sufficient to induce a very clever man to fill the office. For this farthing he should take boats and cargoes under his care for at least ten miles; if two machines were in that space, he should govern both, but if they were twenty miles distant from each other, he should have all goods passing on that pond under his guidance, in which case the agency might be raised. Therefore, averaging the agency at one farthing *per* ton, for ten miles, the expence of it could not be felt on the value of any kind of materials; the agency of one hundred miles being performed for two-pence halfpenny *per* ton. But as even ten-pence *per* ton on one hundred miles would be no object to the seller or buyer of the goods sent, I will therefore raise the agency to one penny *per* ton for ten miles, consequently seventy-five tons *per* day would pay an agent 87l. 10s. *per annum* on a canal with small trade.

Having thus established agents at proper situations, who may be considered somewhat analogous to the book-keeper at a coach-office, also to collectors of turnpikes, *they collecting the tolls*, each proprietor of boats should have his name, and number, marked on each boat.

I will now suppose him to dispatch ten boats, to be left in different places; with these boats he should send a ticket to the first agent, and perhaps to the following effect:

Date.

Date.		Proprietor's Name.								Tons.
To Whom.	Residence.	Boats Number.								
		No.	No.	No.	No.	No.	No.	No.	No.	
A. B.	Manchester,	4	6	10	14					16
C. D.	Stockport,	3	11							8
E. F.	New Bridge,	7								4
G. H.	Romely,	8	9							8
C. W.	Chadkirk,	1								1

The agent, on receipt of such ticket, would draw a line over the numbers to be left in his district, make out a direction for each, and deliver it to the next boatman; with the first ticket to be forwarded to the next agent with such boats as pass over the next machine, and come under his care, and so on. The agent, knowing the time of the boats passing, would also know when the empty boats, or full ones, should return; he would likewise have the boatman on his pond immediately under his control, as well as the men at the machine, therefore could correct any negligence, and the proprietor would know where to apply if they were anywise remiss in their duty. The work might be so regular, as even to ascertain when any particular boats passed each machine, and when it arrived at its destination, by marking the hour on the ticket.

This mode of reducing the work to system, and rendering every man by habit familiar with his part, I conceive, will facilitate navigation, and render the passage of goods of all kinds, to the most distant parts of the country, extremely simple; boats, for instance, from Manchester to London, being carefully packed and covered with a tarpawling, would pass with the ticket, by the various agents,

agents, with the same certainty as others would go thirty miles, one system being preserved throughout*.

The perquisites of the agent, already stated, would be sufficient to warrant the company in demanding a bond to a considerable amount for the true performance of his office; the company would be responsible to the freighter for any losses, and the agent answerable to the company for neglect: this would not only link the various ponds of canal together, but would produce a continued chain of self-interest, the most prevailing stimulus to urge men to be active, and do what is right; the agent's emoluments arising out of the tons conveyed, I conceive to be much better than a fixed salary; as his profits will, in some degree, depend on his attention: which attention might be the means of influencing proprietors of goods to send articles on the canals that might otherwise be transported by different means.

Hence, even by this plan, I see no difficulty in conveying goods into the most distant, and less important, parts of the country; and time, with concurrent circumstances, will no doubt infinitely improve this method.

* It has been observed, that some difficulty would attend sending goods to distant parts by these boats, as a man could not follow his property, or appoint a person to accompany it, in consequence of passing through such various hands and boatmen; but the same objection might arise against the sending of game to London; a man might say he could not go with the game to see it delivered: but, what is much better, agency performs this part of the business, nor do I know any conveyance where property is followed or accompanied by the proprietor. Property is given to the care of others, who are responsible for the delivery into safe hands; letters, for instance, which pass through the various post-offices, are by their size much more liable to miscarriage or mistake, from agency, than a four-ton boat, or goods conveyed by it; yet custom has rendered the transfer of letters perfectly easy and secure, millions of property being conveyed by letters, circulated into the most obscure parts of the country every week.

To

To this regularity, I conceive expedition will, in many cases, be added, as before mentioned of the market, passage, and dispatch boats. Many valuable kinds of merchandize will bear some additional expence in carriage; and it may be of more importance to the merchant to have them in market, in a given time, than to save the difference in expence between the slow and the more rapid conveyance.

I will therefore suppose a canal from the great trading town of Manchester to London, distant 182 miles, to which add 38 miles for the bonds, amounting to 220 miles, and on this length of canal twenty-two agents, one to every ten miles.

A carrier at London, or at Manchester, we suppose to have his dispatch-boats ready, which, containing from four to five tons, might be conveyed at the rate of six miles per hour, by one horse; as they would arrive periodically, each machine-man would know when to look for them; and the boatmen on the various ponds, in like manner, would be prepared with their horses, similar to the operation with the stage-coaches; the boat, thus navigated, would arrive at London, or at Manchester, in about forty hours; of which the expence would be nearly as follows. Allowing one horse to navigate a boat ten miles forwards, and ten back, in twenty-four hours, the horse and driver may be estimated at six shillings, all casualties included; which will amount to three shillings *per* boat for ten miles, and the total expence of ten miles will stand thus:

Three-

	£.	s.	d.
Three-pence per ton per mile to the company,	-	0	10
Horse and boatman,	-	0	3
Agency,	-	0	0
Passing machine,	-	0	0
Wear of the boat,	-	0	0
For 10 miles,	-	0	13
For 220 ditto,	-	14	13

or 3l. 13s. 4d. per ton: what the carrier might expect for his trouble cannot be estimated, but it is probable this mode would not amount to half of what is now paid to broad-wheeled waggons; the expence from London to Manchester being about 8l. 10s. per ton*, and the saving in time would be near three days.

By the slow movement of the boats, every expence, except the horse, will be the same as the above; but by the slow movement a horse would take forty tons twenty miles for six shillings, which is about three-pence halfpenny per boat for ten miles, thus the horse-hire on a boat to London would be

	£.	s.	d.
But by the quick movement the horse-hire is	3	6	0
	2	19	7

which is 14s. 10d. per ton cheaper by the slow than the quick conveyance.

Thus seeing that dispatch may be produced by small boats, they may become the means of conveying passengers, and passage-boats rise to much national importance; a convenience for passengers might be constructed in a boat such as last described, or

* If the tonnage was fixed at two-pence the ton per mile, which would be good tonnage on a canal, the expence to London would be 2l. 15s. per ton, in which case there would be little doubt but the goods might be delivered for half the sum they now cost by waggons.

a boat might be built for the purpose, similar to the First Figure in the Plate of Boats; which I suppose to be thirty feet long, four wide, and twenty feet in the centre for the accommodation of the passengers. This space would give ample room to fifteen persons, which fifteen persons would not weigh one ton and a half on an average; consequently, some repository should be constructed for parcels, to endeavour to complete a cargo, and pay the boatman or proprietor.

I will now suppose such a passage-boat to navigate from London to Manchester. In this case, as the weights would differ in almost every journey, in proportion to the number of passengers, it would be proper to contract with the company at a certain sum *per* mile, loaded or empty; and, as the boat would seldom have more than two tons, such contract at 4d. *per* mile would, perhaps, be the best encouragement to passage-boats, and a fair toll to the company; if so, the expence of such a boat to London would be as follows:

	£.	s.	d.
220 miles at 4d. <i>per</i> mile to the company,	-	3	13 4
Horse hire,	-	3	6 0
Agency, at 22 machines, 2d. each,	-	3	0 8
Passing 22 machines, 2d. each,	-	3	0 8
Wear of boat,	-	3	0 8
Total,	£.	7	10 4

So that fifteen passengers, at 10s. each, would pay the expences; not to mention the carriage of parcels, which are very productive; I will therefore suppose every passenger to pay 20s. that the proprietors

proprietors may be guarded against casualties; yet 20s. would be a cheap conveyance for two hundred and twenty miles, and not one-third of the sum which is now paid to the mail or stage coaches; while the expedition with which the boat may proceed, in consequence of being small, may be equal to the speed of the stage coaches.

Thus we see that the small boats, from being suited to a slow progress, or to the most expeditious conveyance, and being also governed by one regular system, would produce numerous conveniences, well calculated to draw conveyance of all kinds to such canals.

But such convenience never can be attained on the lock principle, for evident reasons: small boats cannot pass locks sufficiently quick; a man could not pass one hundred feet lockage in less than one hour. But a four-ton boat may pass a plane whose perpendicular is two hundred feet in four minutes; besides the loss of water would be so great in locking small boats, as totally to exclude these quick movements; nor could the expedition be performed by a large boat, as the boat in itself is a load for the horse in a quick movement; this, together with the delay of locks, would prevent large boats from reaching London from Manchester in less than nine days, by the usual mode of navigating.

To the advantages enumerated, may also be added, the convenience of short trips to market, or quick communication to and from the manufactories, in the environs of great trading towns. In all such cases, farmers, or manufacturers, may have their private boats, which they may dispatch at pleasure, with

the

the facility of a cart, without waiting for an allocation of interests to compose a cargo, as in large boats; and thus the small boats passing machinery are suited to the various kinds of trade, situations, and circumstances; and have a direct tendency to draw almost the whole carriage of a country into the channels of canal conveyance.

C H A P. VIII

ON THE SAVING OF WATER.

EVERY one acquainted with canals, must be sensible of the importance of saving water, and many have been the expedients resorted to for this purpose; locks being frequently constructed of only four, or four and a half, feet rise, in order to lessen the consumption of this necessary fluid; but so small a rise, on the other hand, increases the operations, and loses some time. Canal acts have also various restrictions on boats passing particular locks, unless the water flows over certain weirs, on particular ponds*. The following calculations will therefore exhibit the proportions of water used at locks, and inclined planes.

8 x 80 x 7.5 = 4800
 625 feet long, seven feet six inches wide; containing one hundred and thirty-three tons of water. A loaded boat, ascending, by pressing its weight (*boat and cargo thirty tons*) into the lower

* Such restrictions may be necessary to save water; but considering canals on the broad scale of national improvement, and individual convenience, it is much the same, as if a cart should not pass a turnpike without a certain load. If a boat must exceed particular dimensions and weight, before it can pass such lock or locks, in seasons when water is scarce, it is evident that boats under such dimensions must return, and their cargoes be transferred to the larger boats belonging to the canal so restricted, or be sent by some other conveyance; which, in either case, is an interruption of free intercourse: on the small boat principle, such restrictions will be useless; if one boat stops, all must stop; wherever one can navigate, all can go; wherever canals extend, whatever may be their weights or their cargo, the use of water will be in proportion.

canal

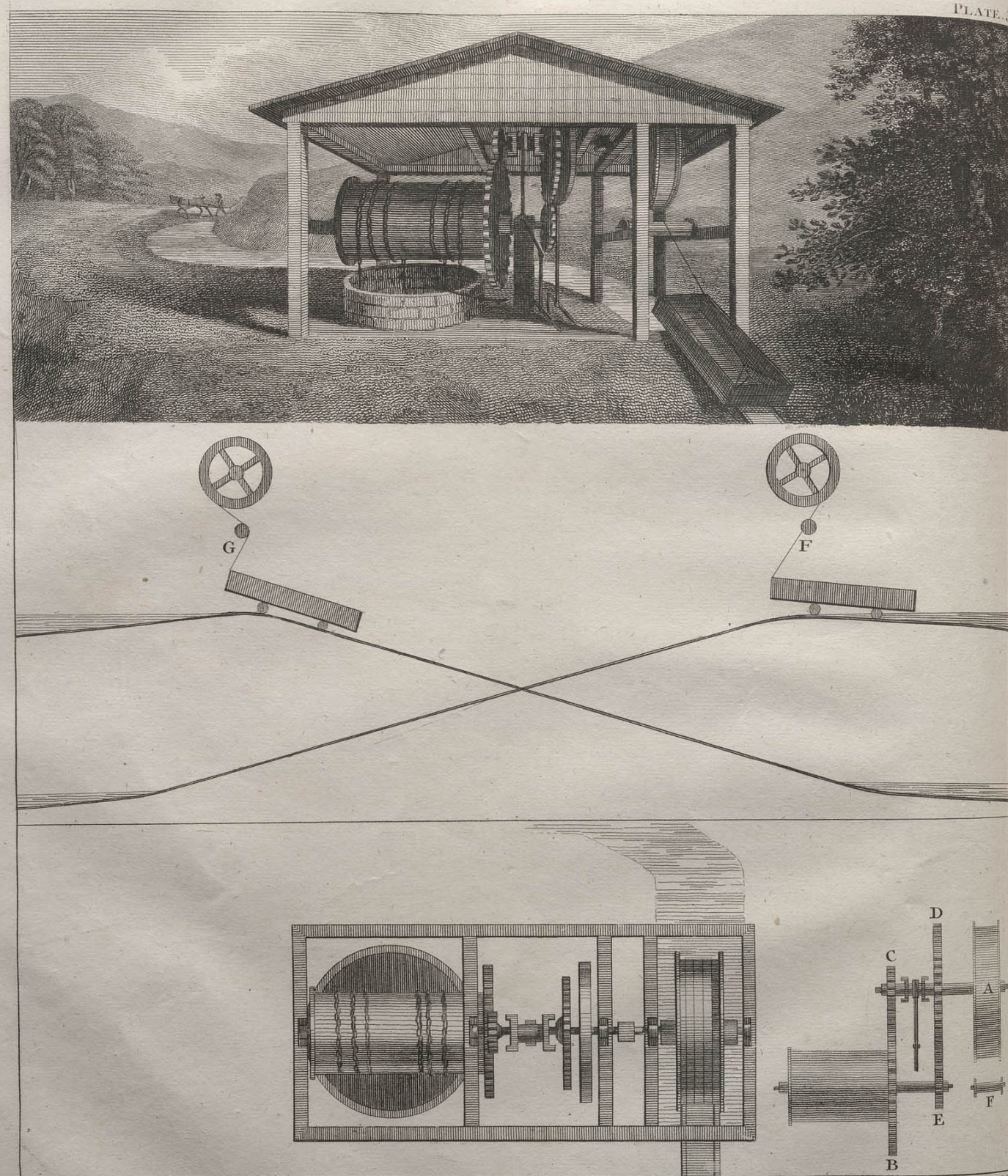
canal from the lock, will require one hundred and sixty-three tons of water to lock to the next ascending pond; while a loaded boat, descending, will press her weight out of the lock into the upper pond, will use one hundred and thirty-three tons in descending; hence the average is one hundred and thirty-three tons, used at every locking. Averaging empty boats in like manner, they will use also one hundred and thirty-three tons. To this it may be said, that two boats will pass with one lock of water; one up and one down; but this can only be the case when two boats fortunately meet at the same lock in that precise order; but as this can be by no means common, it is not worth taking into account; I will therefore allow to every twenty-five tons cargo, *considering empty and full boats*, one hundred and thirty-three tons of water, which, on a trade of five hundred tons *per day*, would amount to two thousand six hundred and sixty tons.

On the inclined plane the boats descending pass without water*, as before observed; it is only the ascending boats which demand water to raise them; and they will have the advantage of a descending boat, to assist in drawing them up: it may therefore be calculated that eight tons of water will raise four tons of cargo, four tons being allowed to ensure an ample weight for the purpose, to overcome friction, and for the weight of the boat itself; hence, if eight tons of water are used to an ascending boat, and none to a descending boat, the average is one ton of water to one of cargo: thus, in a trade of five hundred tons *per day*, five hundred tons of water will be used, which is not one-fifth part of the

* The trifle to the first boat, of about two tons, to raise her on the bridge of the plane, when one thousand tons may pass in rotation afterwards, may be considered as no object.

quantity

quantity in demand for twenty-five ton boats, and locks; or one tenth part of water required in locks for forty-ton boats; independent of leakage at gates, which is very considerable after some years wear. This saving of water will consequently save some expence by the reduction of reservoirs, and materially facilitate all cases of descending trade from high countries; where the saving of water is an important consideration.



The Single Inclined Plane.

London: Published by T & J. Taylor Holborn March 11796.

DESCRIPTION OF THE SINGLE INCLINED PLANE, PLATE III.

THIS plane must be constructed in every respect like one of the planes in the first machine; also the pit, tub, and balance chains, similar; the drum-wheel about the same diameter, and placed over the pit in the same manner; the remainder of the apparatus varying from the first machine, for the following reasons:

On this plane, the boats will both rise and descend; therefore, there is two degrees of power required, and two portions of space to pass through.

The first, in raising the boat out of the upper canal over the bridge of the plane, will not require so much power or space as the second, in raising her from the lower to the upper canal.

To effect this, A, in Fig. III. is a vertical wheel, eight feet diameter*, three or four feet broad on the face, on which the leading chain or rope is to lap; the shaft of this wheel extending towards the drum, has two wheels of different diameters; two of different diameters are also on the drum shaft: suppose the plane four hundred feet long, and the pit one hundred deep, the works

* In this, I shall use round numbers, in order to transmit the idea with greater ease; but the diameters of the wheels must vary, in proportion as the boats pass through more space than the water-tub.

must

must multiply four times in order to raise the boat from the lower to the upper canal; hence let the drum be four feet diameter, B eight feet, C two feet; thus C, and the vertical wheel A, on the same shaft, will make four revolutions, while the drum performs one, and raise the boat four hundred feet while the tub descends one hundred.

Again, when the boat is to be raised out of the upper canal on the bridge of the plane, she will move through a space of about fifty feet, while the tub descends one hundred; thus the speed is reversed, the tub passing through more space than the boat: for this purpose, let the diameter D be eight feet, and the diameter E two feet, *which is half the diameter of the drum*; and the vertical-wheel, A, will perform but one revolution while the drum makes two; and the tub will descend one hundred feet while the boat moves fifty, rising out of the upper canal on the bridge of the plane; thus the two movements are produced by reversing the diameters: and, to cast them in and out of gear, C and D work on a round part of the shafts, and may turn round though the shaft stood still, *which will be the case on the return of the water tub*; between the two there is a boss, on the square part of the shaft, which allows it to move from side to side, but cannot turn except with the shaft: when it is necessary C, and B, should be in action for the quick movement, the boss is cast into C, by means of the lever, and D turns round on the shaft without confining the works; when the slow movement is to be performed, in raising the boat out of the upper canal, the boss is cast into D, and C is left at liberty; by this means, the teeth of the wheels are always in gear, and the boss fixes that to the shaft which is to act, leaving the other to turn as the revolution of its opponent requires; the boss will also

leave both wheels at liberty, as in the Drawing, which must be the case while the tub returns to the top of the pit.

For the purpose of raising the boat out of the upper canal, there is a roller placed beneath the vertical-wheel, as at F and G, Fig. II. round which the chain makes a double; in raising the boat to the upper canal, she must be hooked at the stern, or lower end; and before the chain comes to a perpendicular, under the vertical-wheel, the boat will pass the bridge of the plane and run into the upper canal, conveying with it the chain under the roller, at F, which represents the boat entering the upper canal.

On raising the boat out of the upper canal, she is also hooked behind, as at G; the machine being then put into action, and the chain bearing on the roller G, will draw her over the bridge; when casting off the water-tub, she immediately begins to descend without further trouble, the movement being regulated either by a break or centrifugal fans.

At bottom, she is unhooked, and a boat linked to the chain, the man at top casting the boss into C, draws water into the tub till a power is created; and the boat will rise the plane, pass the bridge, and run into the upper canal, the man casting off the boss on passing the bridge.

The whole of this operation may be performed in six minutes, consequently, four tons up and four down, in six minutes, will amount to nine hundred and sixty tons in twelve hours: should the trade surpass this quantity, the machine may work by night, as mentioned of the first apparatus; consequently, one thousand nine hundred and twenty tons may be performed in twenty-four

hours; which, I hope, exhibits the power of executing a very important trade at a single plane, even admitting the operation twice as long as here estimated; it is therefore well suited to lateral cuts, or such districts as produce about five hundred tons in twelve hours.

Estimate for a single Inclined Plane, one hundred Feet rise, the Plane on an angle of twenty Degrees, the Average of Situations being considered.

	£.	s.	d.
Removing 3000 cube yards in sloping the hill, at 5d.			
per yard, - - - - -	62	10	0
Forming the ends of canal top and bottom, - - - - -	100	0	0
268 yards rubble walling at 5s. per yard, - - - - -	67	0	0
134 yards squared ashlar coping, 18 inches thick, 3 feet long, at 15s. the lineal yard, - - - - -	100	10	0
268 yards cast-iron rails, 100 cwt. per yard, 15s. per cwt. - - - - -	201	0	0
Bedding the rails in the coping, lead and pins, at 2s. per yard, - - - - -	26	6	0
60 Rollers to bear the chains of the plane 5s. each, - - - - -	15	0	0
1 vertical wheel, 8 feet diameter, - - - - -	50	0	0
400 feet chain, 2s. per foot, - - - - -	40	0	0
34 yards tub pit, 11 feet diameter, 4l. 10s. per yard, - - - - -	153	0	0
110 yards fough, at 12s. per yard, - - - - -	66	0	0
1 wrought-iron tub, - - - - -	60	0	0
700 feet chain to the tub, balance, and weight, at 4s. per foot, - - - - -	140	0	0
Drum-wheel, 8 feet long, 4 diameter, spur-gear, &c. - - - - -	100	0	0
Carried over, £. 1,181	6	0	

Pinions,

Brought over, £. 1,181	6	0
Pinions, bofs, and wheels, - - - - -	60	0
Centrifugal fans, or break, - - - - -	40	0
Trough to conduct the water to the pit, - - - - -	10	0
Building to cover and support the works, - - - - -	100	0
	1,391	6
Contingencies, 10 per cent. - - - - -	139	0
Total, £. 1,530	6	0

Locks for 25 ton boats, 100 feet rise, - - - - -	7,000	0	0
Single inclined plane to the same height, - - - - -	1,530	6	0
Saving, - - - - -	£. 5,469	14	0
Locks for 40 ton boats, 100 feet rise, - - - - -	10,000	0	0
Single inclined plane to the same height, - - - - -	1,530	6	0
Saving, - - - - -	£. 8,469	14	0

CHAP. X.

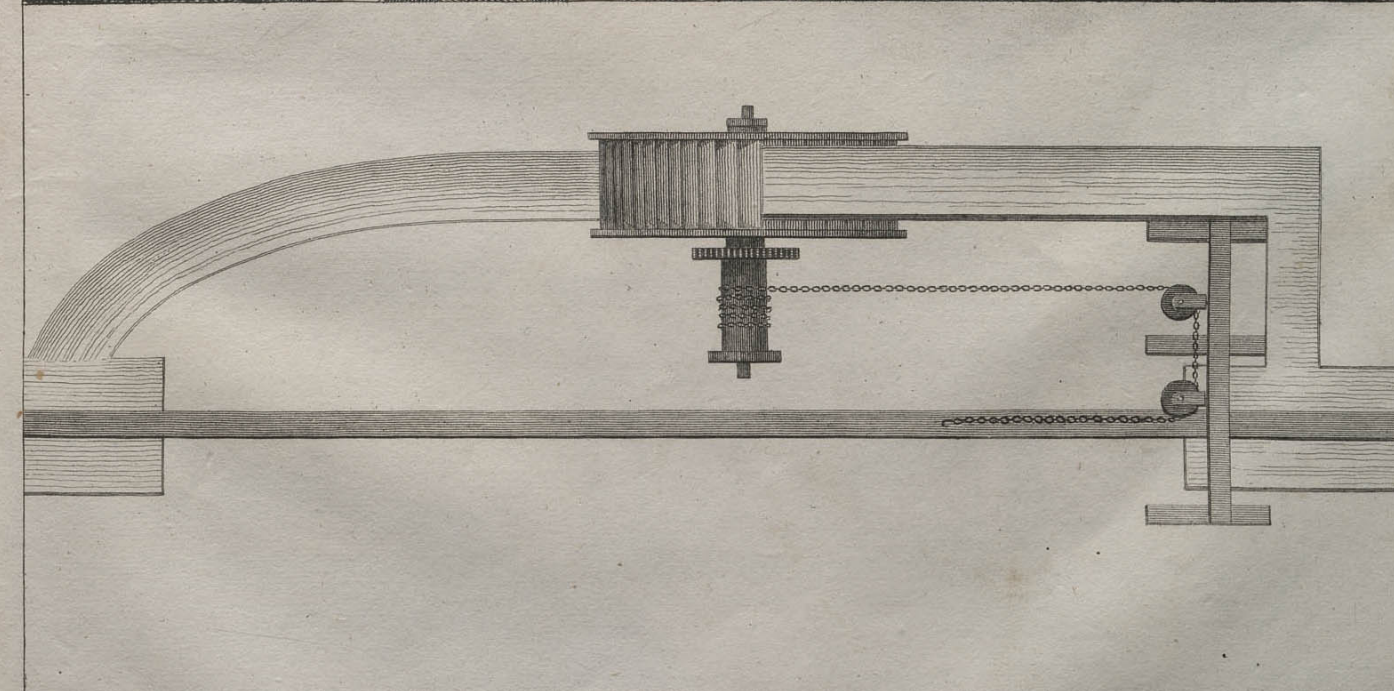
DESCRIPTION OF THE MEDIUM PLANE FOR A SMALL ASCENT, BEING A MEDIUM BETWEEN LOCKS AND PLANES. (PLATE IV.)

IN pursuing the small canal system, long sloping grounds will sometimes intervene, where it would be impossible to obtain a rise of sufficient importance to erect the whole of either of the machines before described, as a building, wheels, &c. would be the same to a twenty as a two hundred feet ascent; the expence would consequently increase on the works, and the number of engine-men would add to the expence of conveyance.

Nor would it be systematic or adviseable to use locks in such situations, although the lock might be so constructed as to take in ten boats at a time, five in length and two in breadth; yet the man separating his line of boats in the centre, and placing them side by side to pass the lock, then forming the line, and again side by side to pass the next lock, and so on, when he could rise or descend but eight feet by such operation, would be a tedious work.

Or if two or three boats only were to pass at a time, the waste of water would be so great as might produce restrictions on passing a small number in dry seasons, as before observed of canals on the lock principle, which would consequently be an interruption of free intercourse; nor could the quick trade, which I have proposed, be conducted with facility by such means.

The



R. Fulton inven. et delin.

The Medium Plane for a small ascent.

London. Published by T. & J. Taylor, Holborn March 1. 1796.

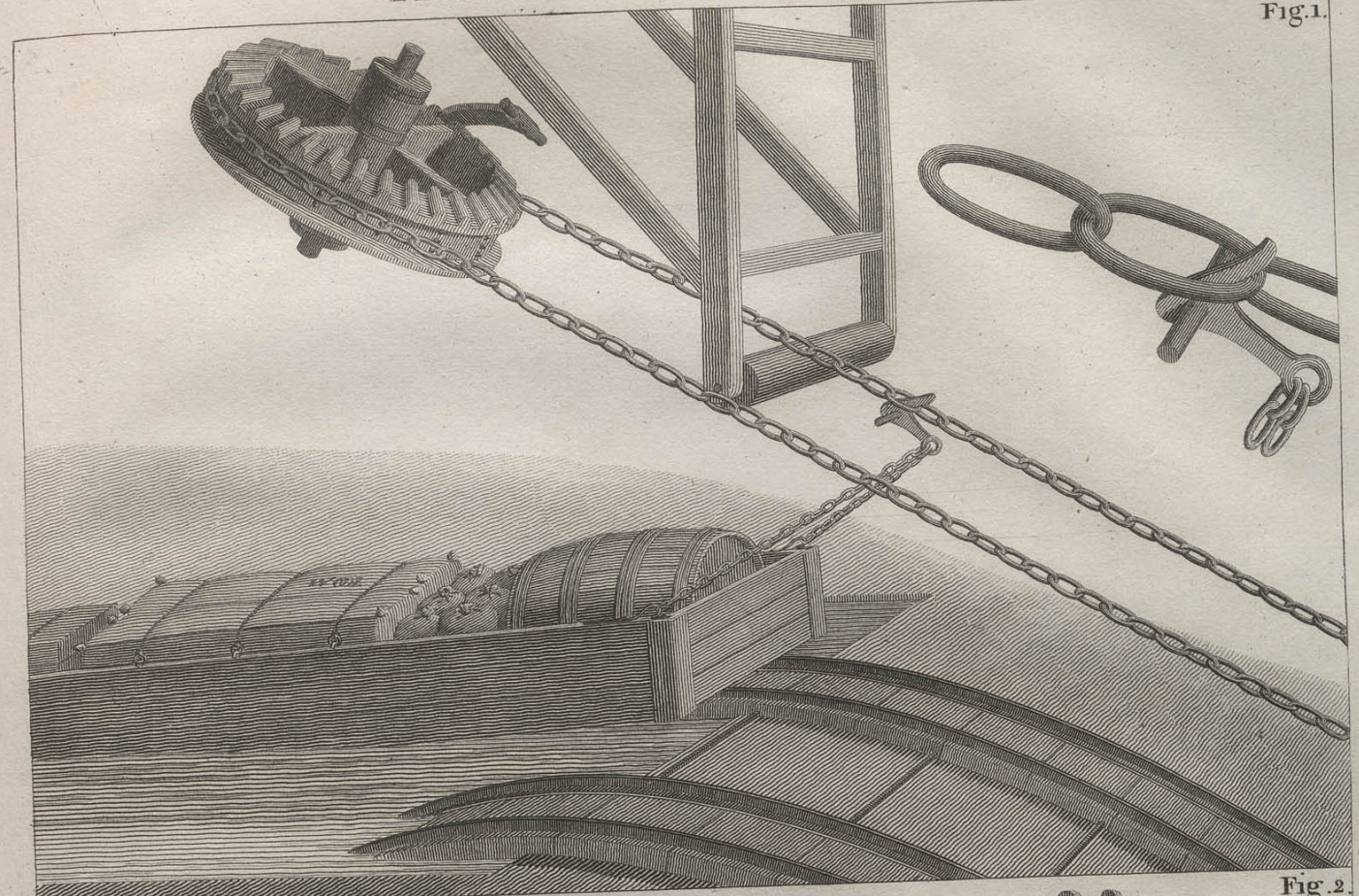
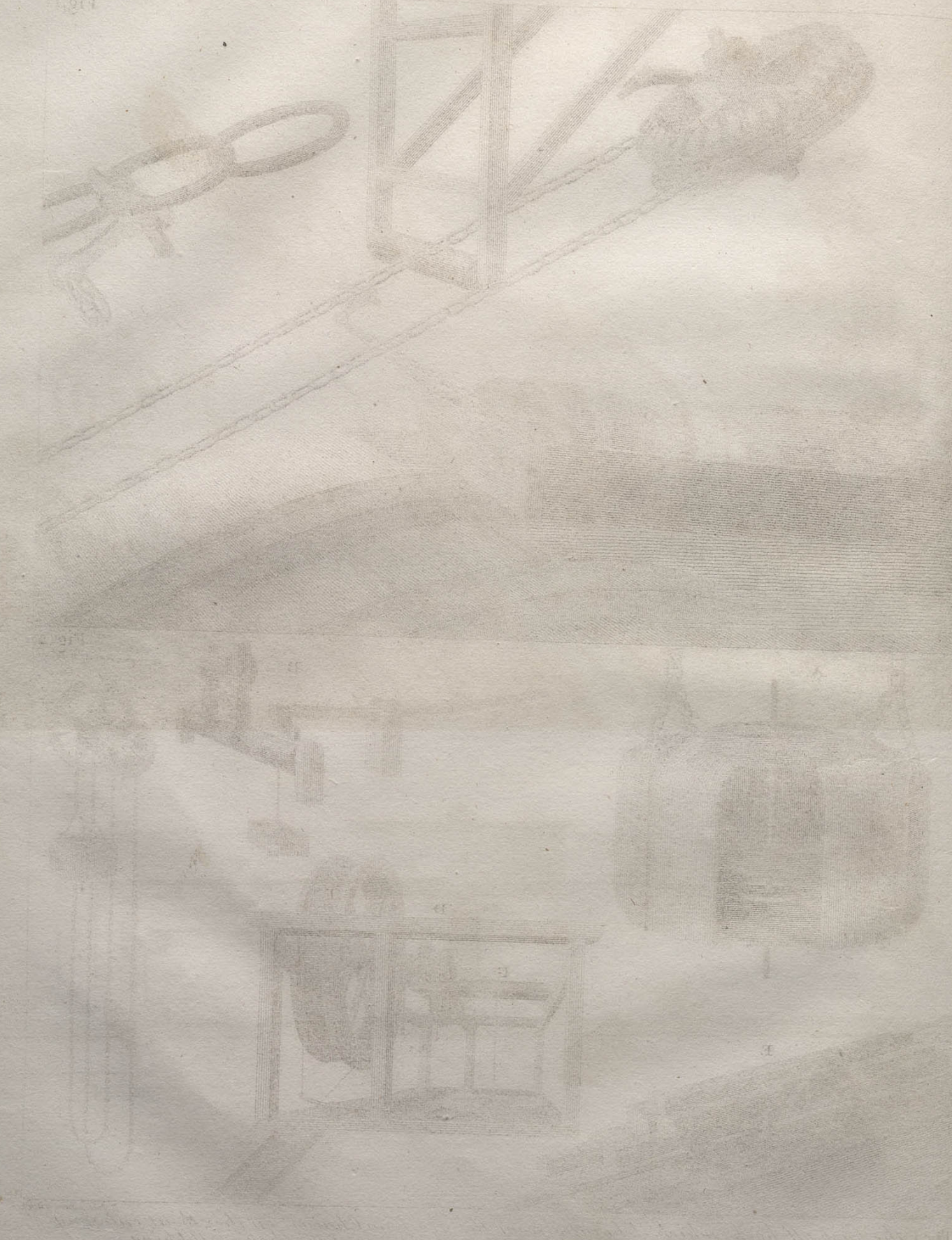


Fig. 2.

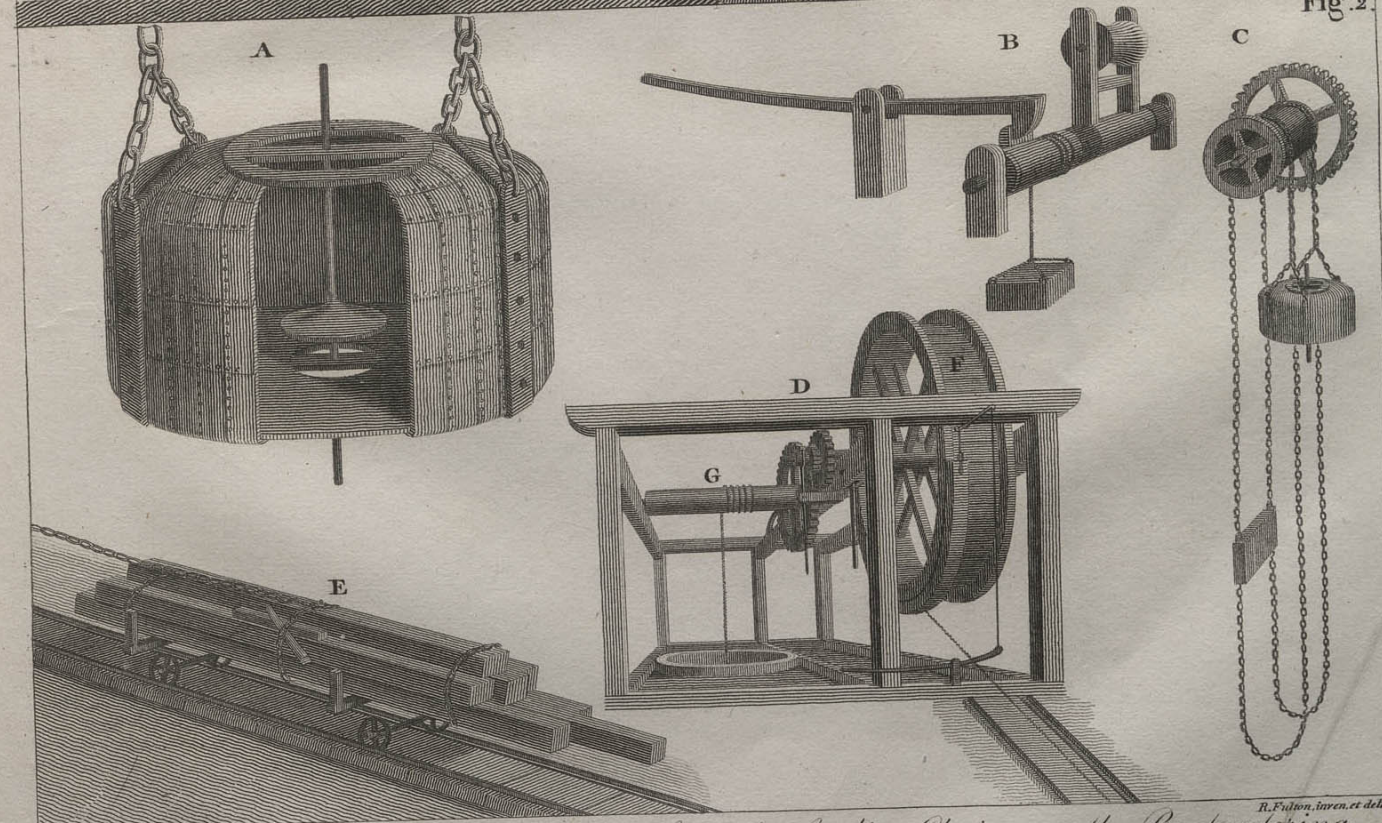


Fig. 1. the Cast off hook, which Separates from the Leading Chains on the Boat entering the Various Levels. Also the Inclined wheel with teeth to prevent the Chain Slipping.
Fig. 2. A the Water Tub, B the Stopper, C the Balance Chains, D the apparatus to Return the empty Boats to the Coal pits &c. E the mode of passing Timbers of any length.
London: Published by I & J Taylor, Holborn, March 1. 1796.

PLATE 6. THE FIRST MODE OF PASSING WIDE AND DEEP VALLEYS.

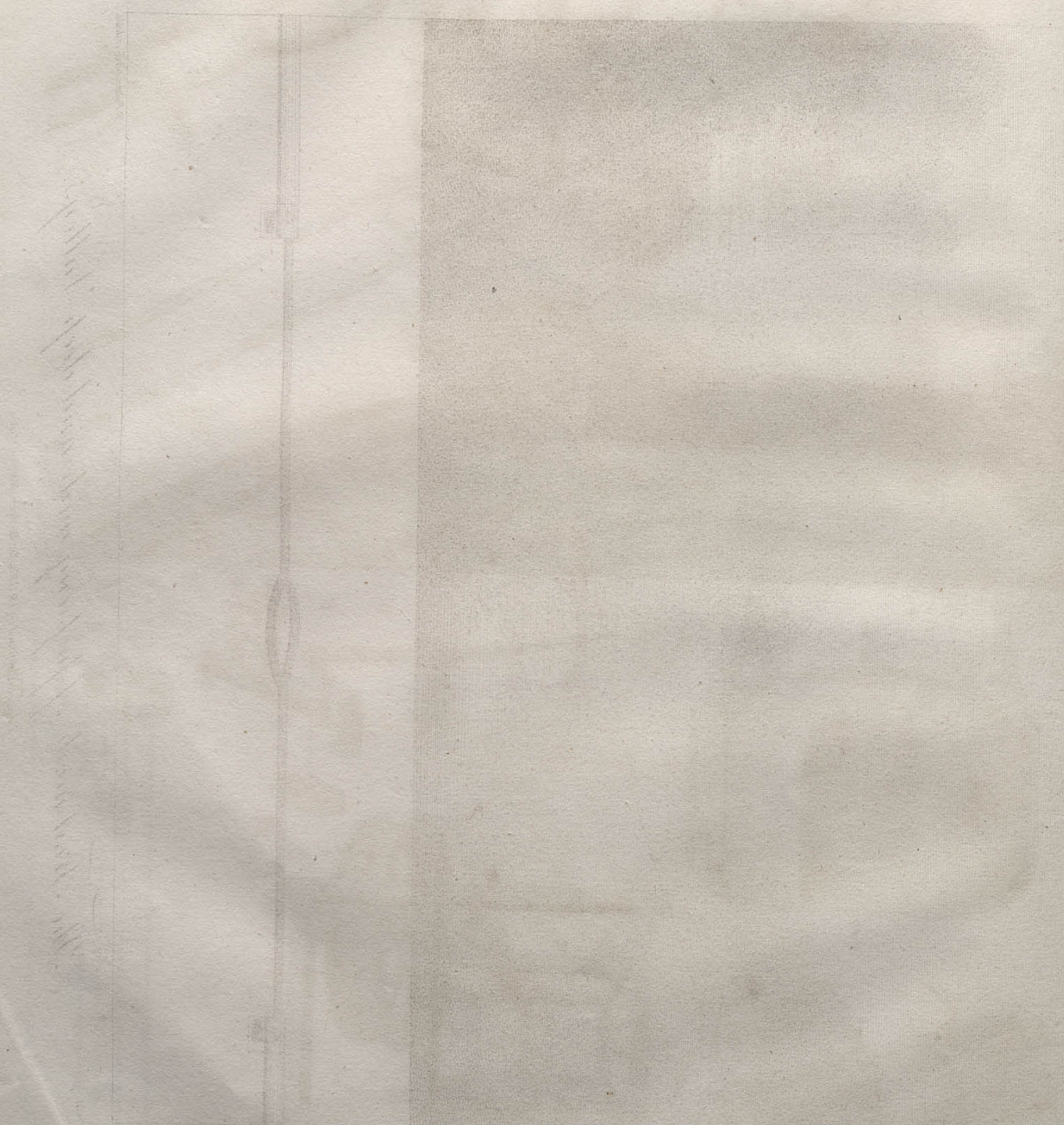
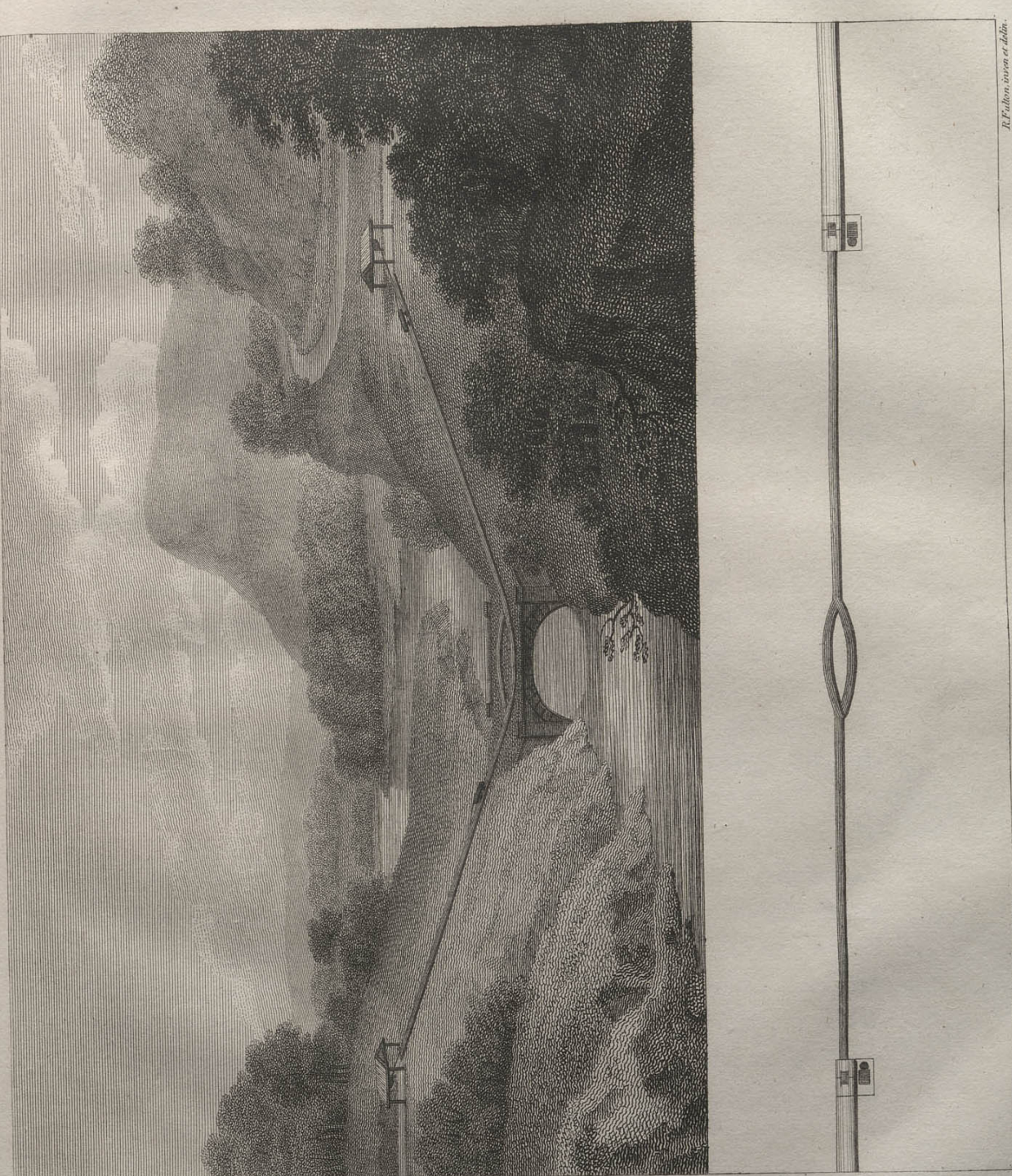


PLATE 6.



By P. Fulton, Architect.

The First mode of passing wide and deep Valleys.

London: Published by T. & C. Taylor, Stationers, North, 1796.

The medium will therefore exhibit the mode of mounting from twenty to thirty feet at one time, which are heights that can be obtained in any country, and probably one or two may rise, sufficient to extend a pond to such situation as will produce a plane of one or two hundred feet perpendicular.

In forming this I will suppose a rise of twenty feet, where a single plane, on an angle of about twenty degrees, is to be extended from one pond to the other; also sixty feet of such plane passing into each canal, turned hollow on entering the lower pond, and bridged on turning into the upper level. On the top and near the centre of the bridge a strong framing is to be constructed, crossing the plane, in which a roller is placed similar to that under the vertical wheel in the last machine, and for the same purpose; two pulleys are also fixed to the frame in order to guide the leading chains over the centre of the plain.

A water-wheel must then be erected near the side of the plain to create the necessary power (*see the Ground Plan*), on the shaft of which a pinion working in a wheel will put a roller or drum in motion, on which the leading chains are to lap, which roller may be cast in and out of gear by a lever; three hundred and fifty feet of chain must then be fixed to the roller, and pass through the pulleys over the plane.

I will now suppose ten or any less number of boats ready to descend at one operation; the leading chain, making a double under the roller, is hooked to the stern of the third boat; and the wheel being put in motion it will draw the three first boats over the bridge of the plane, the other seven following: the three boats being now on the sharp angle will have power sufficient to draw
out

out the remainder; the water is then stopped from the wheel, and the chain still continuing hooked to the boat, they will begin to descend in regular rotation; the chain, descending with the boats, will turn the water-wheel backwards and answer as a break to regulate the velocity. On a man arriving at a plane the whole operation is to hook the chain to the third boat, if there are three, or to the stern of one, if there is no more, and set the wheel in motion; on that boat to which the chain is hooked, mounting the bridge, the water is stopped from the wheel, and the whole line of boats begin immediately to descend into the lower canal; during which the man attends to the break, and the time in performing this operation, I conceive, will be as follows:

	Minutes.
Hooking the leading chain, - - - -	3
Drawing the first boat out with the wheel, - - - -	1
Descending the plane, - - - -	1
Unhooking the leading chain and applying the horse, - - - -	2
	7

Hence, in a descending trade, forty tons may pass in seven minutes.

In ascending, the speed will consequently be in proportion to the power of the water-wheel; it will therefore be adviseable to give power to the wheel in order to save time; in rising there will be three boats out of water on the plane at a time, the plane out of water being sixty feet long; the boats and their cargoes will weigh about seventeen tons, this, on a plane of twenty degrees, will be a resistance of about five tons, friction considered, perhaps six tons; to raise this if I suppose an overfall wheel fifteen feet diameter, and the roller

roller on which the chain laps one foot and a quarter, or to that effect, by tooth on pinion, the power will increase as one to twelve, and one ton actual purchase on the wheel will raise twelve on the plane; the wheel should therefore be constructed to give one and a half tons purchase, or nearly so; and, for this purpose, should hold about two tons of water; such a wheel would perform twelve revolutions in one minute, and draw the boats forty-five feet up the plane in that time, or two hundred and seventy feet in six minutes, by which they would enter the upper canal.

To perform this operation, the leading chain is continued over the ten boats in the lower canal, and hooked to the stern of the last boat; the hook of each boat is also fixed in a link of the chain; thus the ten chains, being hooked to the leading chain, the wheel is put in motion, and the whole moving forwards ascend the plane, casting off from the leading chain as they pass the bridge, and run into the upper canal, where they are immediately ready for navigation: the whole of this ascending operation may be performed in ten minutes, the descending boats being passed in seven, the average may be estimated nine minutes; hence, forty tons passing in nine minutes, three thousand two hundred may be transferred in twelve hours.

By the before calculation on the water-wheel, in which a very sufficient power is allowed to raise forty tons of cargo, twenty feet would require, - - - - 288 tons water.
In forty tons descending - - - - 48 tons do.

336

This

This will average one hundred and sixty-eight tons of water to forty of cargo, one, two, or more, boats using water in proportion; but a lock to raise forty tons would require about two hundred and sixty-six tons; hence there is some water saved. It is also probable, that these machines will be constructed on the lower ponds, where water will not be so important, the supply being obtained with greater ease; the following will exhibit the expence of constructing such an apparatus:

Estimate for a Medium Twenty Feet Rise.

	£.	s.	d.
180 feet plane, 1l. 10s. per foot,	270	0	0
Water-wheel,	100	0	0
Drum-wheel, and pinion,	40	0	0
350 feet chain, at 4s. per foot,	70	0	0
Wheel leet,	60	0	0
Trough,	10	0	0
Two large Pulleys	2	0	0
Timber and workmanship,	60	0	0
	612	0	0
Contingencies 10 per cent.	61	4	0
Total,	£. 673	16	0
Locks for 25 ton boats, twenty feet rise,	1,400	0	0
Medium,	673	4	0
Saving,	£. 726	16	0

Locks for 40 ton boats, 20 feet rise,	-	-	£. 2,000	0	0
Medium,	-	-	673	4	0
Saving,	-	-	1,326	16	0

This machine harmonizes the whole system of small canals, and fits them to every situation (*where water can be found*), and preserves regularity.

C H A P. XI.

OF CONSTRUCTING AQUEDUCTS.

HAVING exhibited the mode of passing the boats to and from the different ponds of canal, and shewn the great difference in expence between the method described, and locks; the next consideration of the most importance, in prosecuting navigations, is the expence of constructing AQUEDUCTS.

In seeking to extend the benefit of water-carriage, and pass to certain towns or districts by the nearest rout, wide and deep valleys will frequently present their extensive chasms, and seem to exclude connection; which, on the lock principle, would, in numerous instances, be the case; for if I suppose a valley two hundred feet deep, and six hundred yards wide, what country could produce a trade to pay for an aqueduct in such a situation? That there are an infinite number of similar situations, where it would be desirable to pass in order to open a near communication, I conceive no one will deny; and in such a situation, 200,000l. would not pay the expence of an aqueduct. To lock down and up would be almost equally difficult, considering waste of water and loss of time; and, if practicable, to go by a circuitous rout, the distance might to be so great as raise the material to the expence of land-carriage: consequently, the happy effect of a water intercourse between such districts, could never be experienced on the lock system. But, to surmount these difficulties, and open an easy communication, see Plate VI. representing the CONJUNCTION.

This

This is simply two single inclined planes in conjunction, expanding from hill to hill, and binding the two countries in the bonds of reciprocity.

Each plane extending down the side of the hill, they are united at bottom by a double plane, in the form of a long oval, on which the boats pass each other. *See the Ground Plan.* On the ends of the oval, there are guides working on a bolt, which move from side to side of the plane alternately, as the boats pass, which prevents the two boats ever landing on one plane, or interrupting the passage of each other.

In this the operation at top is exactly the same as the single inclined plane; but at bottom a man is placed where the boats are to pass; and on each engine letting down a boat, the man at bottom removes the chain from one boat to the other, and giving the signal to the men above, each draws up his opponent's boat; thus they are transferred across the valley to the different ponds of canal.

In performing the operation on the single plane, six minutes is allowed to pass two boats, one down and one up; in doing this, the time will not be much more; for each man at top working at the same time the same operation, the two boats will be moving down the planes towards the centre at the same time, where the man can transfer the chains in nearly the same time that he could hook a boat; but as they may not all work regularly at the same time, I will allow eight minutes to each operation, amounting to one ton per minute, or seven hundred and twenty in twelve hours, or one thousand four hundred and forty in twenty-four hours; a quantity sufficient to shew, that if each

M 2

operation

operation was much longer than here estimated, yet a very important trade may be performed.

In the estimate of expences, each man letting down and raising a boat for threepence*; and the man at bottom transferring the chains for threepence on two boats, would amount to one penny and a fraction per ton; but considering empty with full boats, I will allow one penny halfpenny per ton for passing this apparatus, which I conceive adequate to every contingency; and the following will exhibit the probable expence of constructing the machine.

Estimate for a Conjunction Two Hundred Feet high, Six Hundred Yards in Width.

First Half.	£.	s.	d.
380 yards inclined plane, 4l. 10s. per yard,	1,710	0	0
67 yards tub pit, 4l. 15s. per yard,	318	0	0
320 yards fough, 15s. per yard,	240	0	0
Vertical-wheel,	50	0	0
1,000 feet chain, at 2s. per foot,	100	0	0
Wrought-iron tub,	60	0	0
1,400 feet tub and balance chains, at 4s. per foot,	280	0	0
Drum-wheel,	100	0	0
Pinions, bobs, and levers,	60	0	0
Carried over,	£. 2,918	0	0

* Threepence for two boats I consider sufficient wages, when it is considered a man will pass forty boats, amounting to 5s. in five hours and twenty minutes; hence, in working twelve hours, in a brisk trade, he might earn 11s. 10d. halfpenny, a sum sufficient to support different sets of men.

Brought

Brought over,	£. 2,918	0	0
Centrifugal fans,	60	0	0
Building and timber to support the works,	200	0	0
	3,178	0	0
Second Half,	3,178	0	0
	6,356	0	0
In the passing place, 60 yards plane, 4l. 10s. per yard,	270	0	0
Culvert or bridge,	200	0	0
	6,826	0	0
Contingencies 10 per cent.	682	10	0
Total,	£. 7,508	10	0

As the whole water used in raising the boats will descend to the valley, and be lost from the canal, it will amount, on a trade of five hundred tons per day, to about two thousand tons waste, equal to about eight lockings for forty-ton boats, which passing from the upper ponds of canal, where water is scarce, to the lower, where it is of little importance, water being there more abundant from various sources, is similar to the above waste.

In constructing the conjunction, there is also the advantage of gaining height; one plane may rise higher than the other if necessary, and thus gain any number of feet which the ground will admit of, yet perform the transfer with the same facility; and if one pond must be replenished with water from the other, a pipe may be laid along the side of the planes for that purpose.

Having

Having exhibited the difficulties which may be overcome by this machine; I hope criticism will pardon my attempting to display the advantages which will accrue, if I estimate the probable expence of a canal without seeing the ground.

But suppose it necessary to supply a town with the very necessary article of coal, the works distant ten miles with such a valley, and two hundred feet rise intervening; in this, which is rather a difficult situation, the expence would probably be as follows:

	£.	s.	d.
Constructing the conjunction, - - -	7,508	10	0
Two single inclined planes, 100 feet rise each, -	3,056	6	0
Reservoir, - - - - -	3,000	0	0
Land, 5 acres per mile, 100 l. per acre, -	5,000	0	0
Cutting, planting quick, &c. 500 l. per mile, -	5,000	0	0
Bridges and culverts, 300 l. per mile, -	3,000	0	0
	26,564	16	0
Contingencies, act of Parliament, &c. -	2,656	9	7
	£. 29,221	5	7
The interest of 29,221 l. 5s. 7d. at 5 per cent. per ann. - - - -	1,461	1	3
On this canal, 50 tons per day, allowing 280 working days, and 3d. per ton per mile, would produce, per annum, - - -	1,750	0	0
Which, after paying the subscribers 5 per cent. leaves for agency and repairs, - -	£. 288	18	9

Thus,

Thus, on a trade of no more than fifty tons per day, the subscribers would have a fair prospect of receiving 5 per cent. And although threepence per mile may appear high tonnage for coals, yet they arrive at town for the following sum per ton, carriage:

	s.	d.
Threepence per ton per mile to the company, -	2	6
Passing two inclined planes, - - - - -	0	2
Passing the conjunction, - - - - -	0	1½
Boatman 6s. 8d. per day, or to that amount, conveying 10 loaded, and returning 10 empty, boats in one day, - - - - -	0	2

Total per ton for ten miles, - - - -	2	11½
Which could not be conveyed by land for less than	7	6

Hence a saving to the inhabitants per ton, - 4 6½

Which might produce a further saving as the trade increased; in which case the tonnage should be lowered: when one hundred tons per day is performed, and the company receive more than 10 per cent. the tonnage by the act should be reduced, on rude produce, to 2d. per mile.

When one hundred and fifty tons per day is performed, and the company receive more than 15 per cent. the tonnage or rude produce should be three halfpence per mile, but never lower by the act; competition among canals will regulate the carriage of course, and competition will be a benefit to the county. It is therefore good policy in Parliament, to allow ample tonnage, that subscribers may have a prospect of a return on a small trade, which

which will be an encouragement to speculators; the reduction of tonnage on rude produce to be governed by the returns; but on merchandize, to stipulate for a certain sum, which the proprietors might reduce as policy dictates. And thus canals will be extended in every direction, in consequence of the best of all encouragement, that of receiving a fair interest on a small trade; and the prospect of this interest increasing to a very important return of wealth from a small capital.

London: Published by I. & J. Taylor, Stationers, Strand, 1796.

The mode of passing Rivers and gaining height at the same time.



PLATE 7.

CHAP. XII.

THE MODE OF CROSSING RIVERS AND GAINING HEIGHT AT THE SAME TIME, PERFORMING THE DOUBLE OPERATION OF AN AQUEDUCT AND LOCKS. (PLATE VII.)

THIS apparatus is the double-inclined plane in all its parts, either for a descending or alternate trade; the stone piers supporting iron rails which compose the plane.

It would be difficult to draw the exact difference, in expence, between this machine and an aqueduct to cross a river, than locks to gain height; but if the immense labour in constructing an extensive and high aqueduct is considered, I conceive the saving will be found very important. The great quantities of stone (*which should be of a good quality*), hewn to certain squares and templets; the frequent long carriage, the timber for centres, and the various preparatory works, all tend to load aqueducts with heavy expences, and render them one of the greatest obstacles in prosecuting canals.

If I suppose it necessary to carry a canal one hundred feet high *, and three hundred feet in length, over a river, it is a moderate calculation, considering the average of situations, to estimate it at the round sum of

	£20,000
To which add one hundred feet lockage for twenty-five ton boats,	7,000
Amounting to	£. 27,000

* There are some aqueducts in contemplation of greater dimensions than here specified.

Yet a similar situation may be crossed, and the height gained, in one movement, as appears by calculation, for about 8,000l.; consequently 19,000l. is saved, which is almost the whole expence of the aqueduct.

Without entering into tedious estimates to prove this, I conceive the common sense of those who have the least knowledge of the subject, will inform them of the reason of these savings; but to the speculating reader, if he observes by the plate that the part crossing the river is a simple stage, the weight of which, compared with the load of water and stone which press on the piers of an aqueduct, is trifling; consequently the piers are but as columns without arches, and the masonry, which in aqueducts is almost the whole expence, is here so contracted as to be, comparatively, scarce worth mentioning; iron arches or braces being adopted, the expence of which is not more than the centres to build an arch of stone, and the continued plane performing the part of locks, of which he has had a comparative view, I conceive it will exhibit the obvious reason of such important savings.

This combination is indeed so material, that, in projecting a line of canal where a river or deep valley is to be crossed, it should be well considered, whether it can conveniently be brought to such a situation that the ground will admit of rising at the time of crossing; which, even on the small system, will save time and expence.

The second mode of passing Rivers. Independent of Aqueducts.

London: Published by T. & A. Neave, 1808.



PLATE 8.

CHAP. XIII.

PLATE VIII. represents the parallel plane for such situations where height cannot be obtained; it is to extend across the river, or valley, and descends about sixty feet into each canal.

On each end, and over the canal, a horizontal wheel is placed, to one of which is fixed the whole machinery, *except the preparer and stopper*, of the double-inclined plane; the chains performing the rotatory movement.

To pass the boats, one is hooked to each chain; after which, water being drawn into the tub till a power is created, the boats will rise on the plane, passing to the different ponds of canal, and so on, in regular rotation.

This is the most expeditious of all the machines: the man having little more to do than hook the boats to the chains, and draw water into the tub; the cast off hooks acting as in the double plane. In this the water to pass the boats descends to the river, or valley, and is lost to the canal; but as this plane is level, the resistance will not be great; in proportion as the length of the plane is to the depth of the pit, water will be required; but averaging situations, one ton of water will pass one of cargo: while its expence, considering the various situations and circumstances, will be about one third the sum necessary to an aqueduct.

But although rivers, or valleys, may be passed with ease by the three modes described, yet, in many instances, it will be adviseable

to construct aqueducts, particularly where there is no great difficulties to encounter; which aqueducts may be formed of iron, as in *Plate XIII.* averaging the situations, much cheaper than of stone.

But the decision on the erecting of an aqueduct, or its particular construction, must depend on a variety of circumstances; such as, the supply of water, saving of time, carriage of stone, or iron, &c. &c. adopting that mode which will on investigation produce the greatest saving, yet answer the intended purpose.

CHAP.

CHAP. XIV.

ON PERPENDICULAR LIFTS TO PASS BOATS.

ALTHOUGH I have already explained the mode of passing the boats, which, I conceive, will be productive of systematic navigation, and ought to be universally adopted till a better is discovered; yet the four following Plates will exhibit machines for transferring the boat by perpendicular lift. These machines were originally intended for small canals, as lateral cuts from those of greater dimensions, in order to extend into such districts as could produce from fifty to four hundred tons per day; principally to convey manure and fuel, and thereby relieve the country by a medium carriage, between the large canals and cartage.

This, for a long time, was the extent of my thoughts; the idea of an universal system did not arise, till I discovered the great saving which would be produced by such lateral cuts. I then wished to render the canal equal to a trade of more than four hundred tons per day, and capable of performing the work of a large canal; in which, there was nothing wanting but an improvement in the machinery to produce expedition; but this baffled every experiment for some months. At length the rotatory movement, and boats with wheels, occurred; and they exhibited the power of passing valleys. On revolving the thought, I found it would answer the purpose, by performing the most important trade, producing system, and simplifying the machinery: it has consequently raised small canals (*in my opinion*) from lateral cuts, to the most extensive and important communications.

CHAP.

CHAP. XV.

DESCRIPTION OF THE PERPENDICULAR LIFT, PLATE IX AND X.

IN constructing this apparatus, the canal being run to such a point of a hill as will admit of a quick rise; the hill, if steep, may be laid open, as in the Plate, or have two pits sunk equal in depth to the difference between the levels of the two canals; one of the pits of an oval form, and sufficiently large to suffer a boat twenty feet long, four feet six wide, to pass through; the other, eleven feet diameter, for a preponderating tub. The two to be united to the canal by a tunnel.

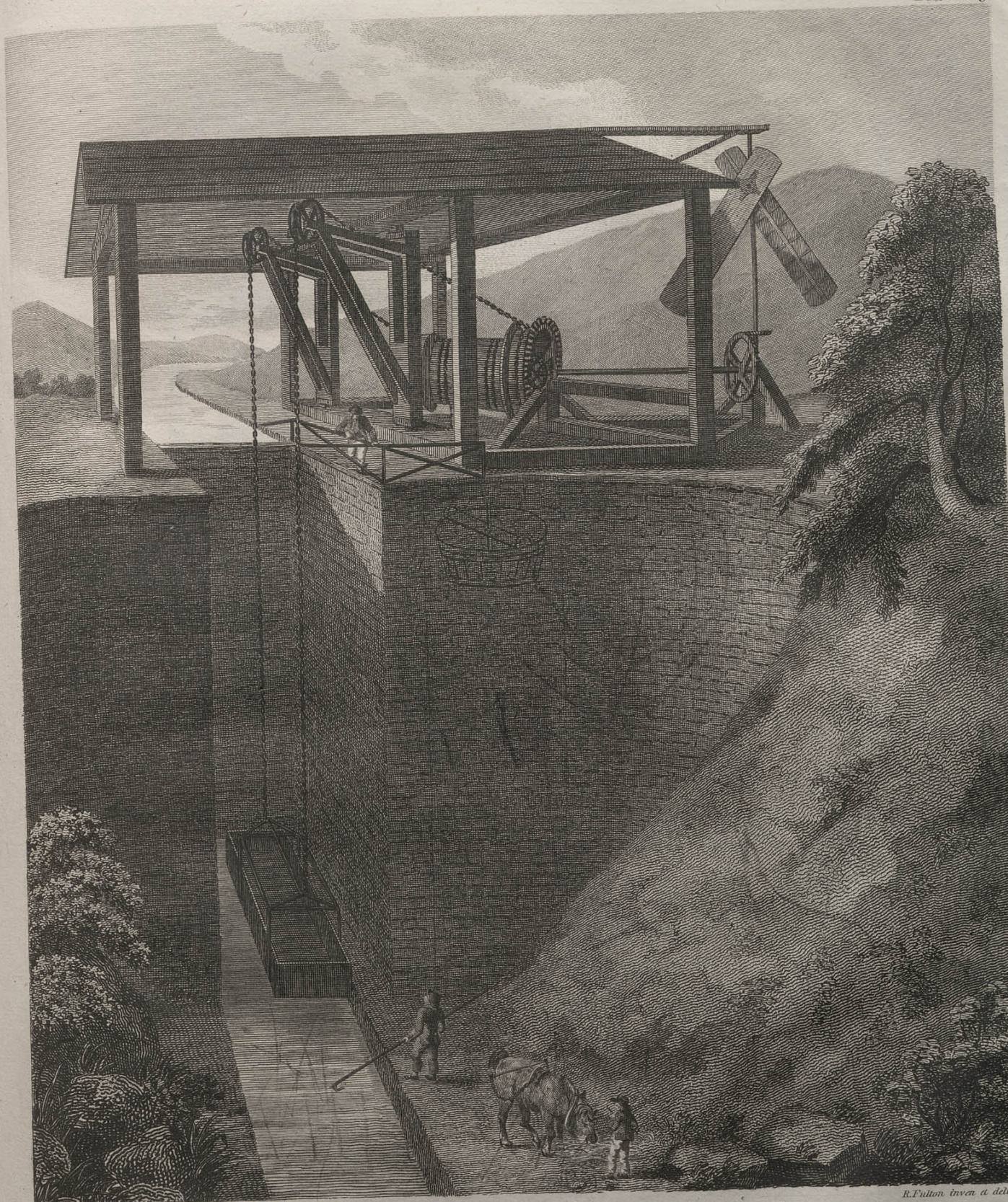
Having formed the tunnel and pits, two cranes are to be constructed, each fifteen feet high, capable of bearing three tons each, which must be placed on the side of the upper canal, and opposite the junction of the canal and pit, as in Plate X.

Those cranes must stand twelve feet apart from gudgeon to gudgeon, and their gibs to be united by a lever, also twelve feet long, as at A in Plate X.; by this means, the cranes will ever move parallel to each other, and keep their chains equi-distant.

Behind the cranes, and over the pit C, there is a drum-wheel of two diameters; to the largest the crane chains are fastened, and those of the tub to the small diameter; to the crane-chains a cage of iron is fixed to receive the boat; thus suspended, the cage and tub will move alternately between the summit and lower canals.

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For



The perpendicular Lift for passing an alternate Trade.

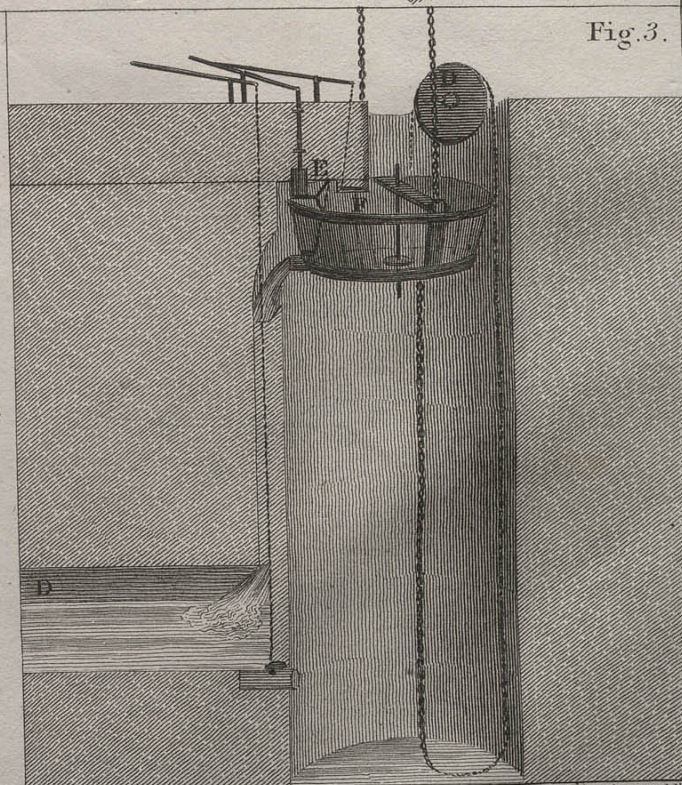
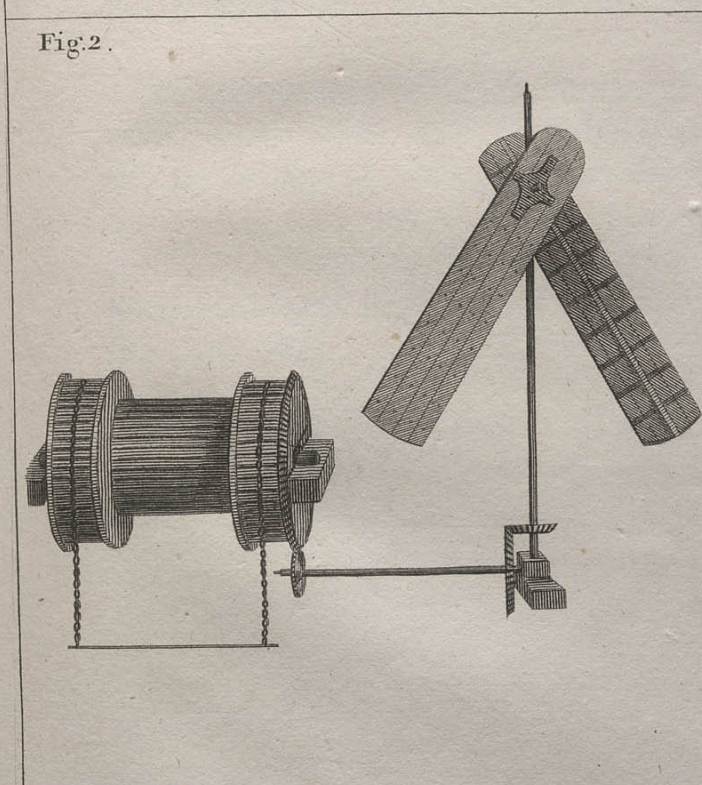
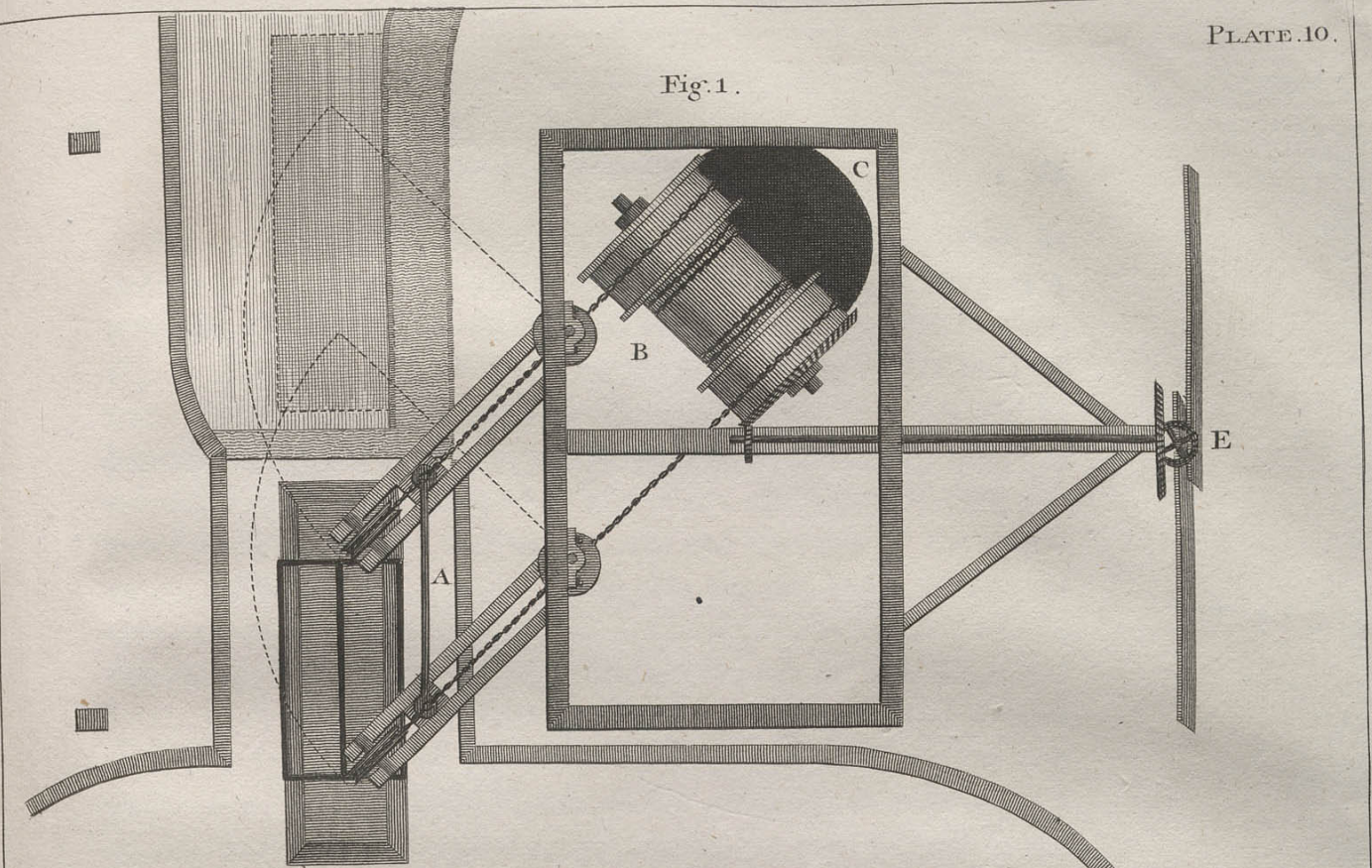
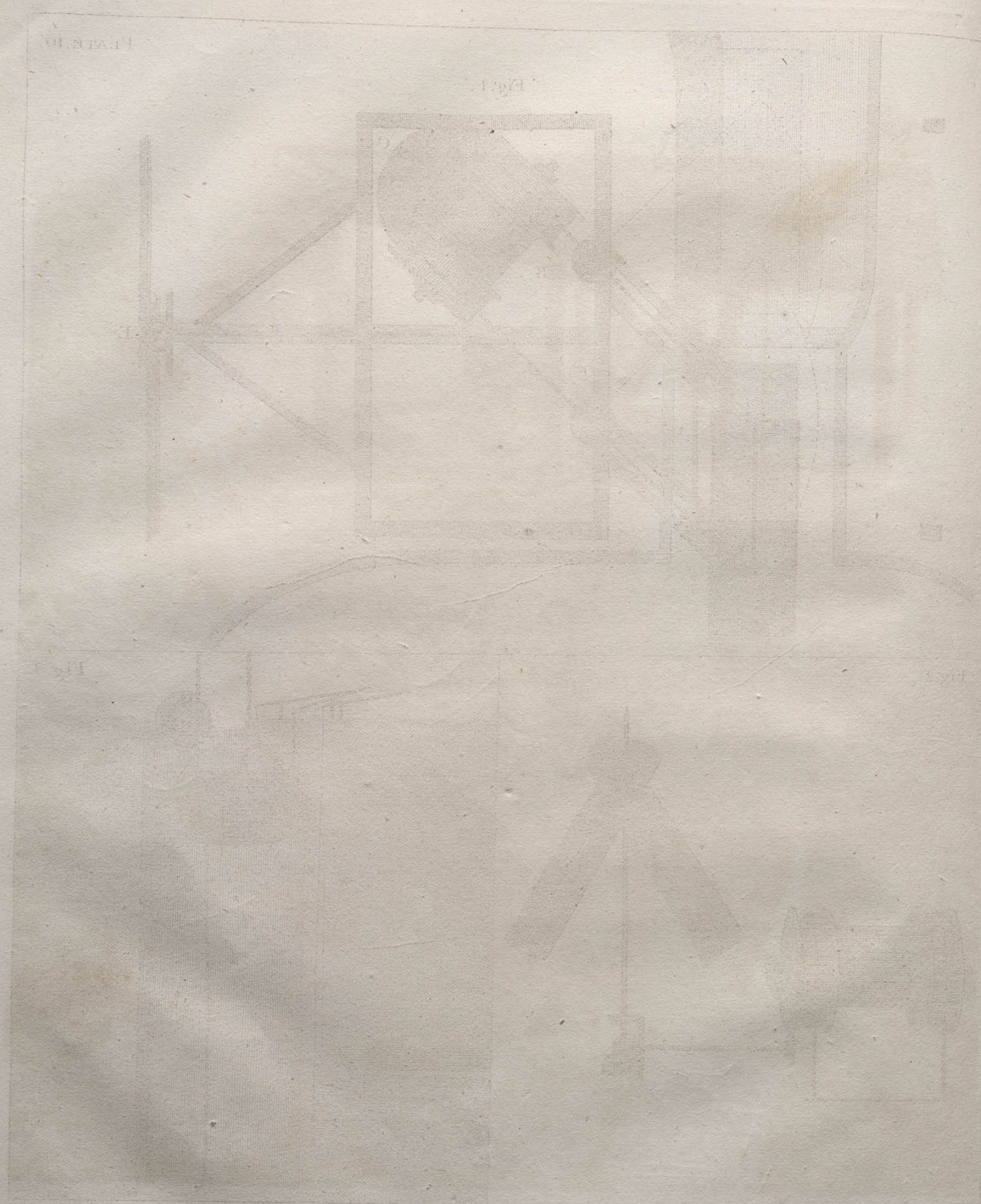


Fig. 1. Plan of the Machinery with the mode of keeping the Cranes parallel by the Lever A.
 Fig. 2. The drum Wheel and Centrifugal Fans
 Fig. 3. The Water tub with the mode of discharging the Raised Water into the Reservoir D.

For the purpose of raising the boat out of the upper canal, in order to move her over the pit previous to descending, there is a reservoir, D, formed in the side of the tub-pit near the bottom, *Fig. 3. Plate 10*, and of a size to contain about thirty tons of water: at the time the cage is in the upper canal, the tub will be beneath this reservoir, from which water must be drawn into the tub till a preponderating power is created; the tub will then descend about eight feet, raising the cage and boat out of the upper canal. The cranes are then moved over the pit, and a portion of water discharged from the tub, till the boat preponderates; which, descending to the lower canal, will raise the tub to near the upper level, in the situation exhibited in the third Figure; where a valve opening, by means of the lever at E, the water from the tub passes into a pipe, and descends to the reservoir, *in order to raise the next boat out of the upper canal*, leaving the boat to float in the lower pond.

To raise a boat from the lower pond, and pass her into the upper canal, water must be drawn from the upper canal into the tub by the pipe F, till a preponderating power is created; which descending, will raise the boat about one foot above the upper pond; the cranes are then turned over the canal, and the water being discharged from the tub, the boat will immediately float in the upper level.

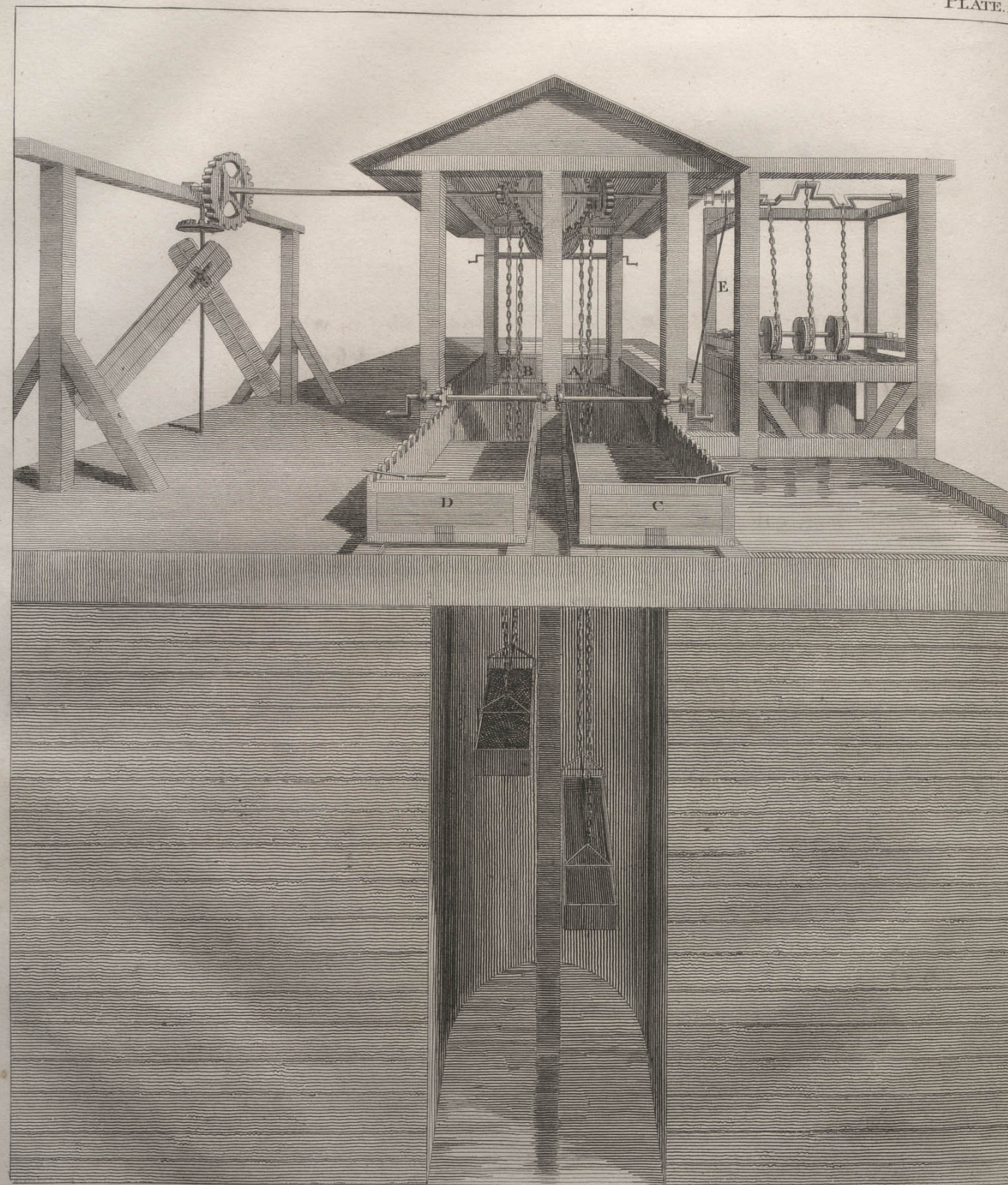
To regulate the movement of this machine, the centrifugal fans are applied, as represented in Plate IX. Also the balance chains to the tub, as in Plate X. *Fig. III.*

CHAP.

The

The operation of this machine is easily performed, and a four-ton boat may be transferred through a space of one hundred feet high, in eight minutes, or three hundred and sixty tons in twelve hours.

The expence of constructing one hundred foot lift, averaging the situations, will be about 2,500l.



*The mode of passing a descending trade and saving the Whole of
the Water by means of the pumps.*

London: Published by T. & J. Taylor, Holborn March 1796.

C H A P. XVI.

DESCRIPTION OF PLATE XI.

EXHIBITING a machine for a descending trade, in which the whole of the water is saved, while the trade descends; yet should it be found necessary, by a further extension of the canal, to form the apparatus for an alternate trade, the water tubs may be applied.

In the first case of a descending trade, there is but one pit, which must be thirty feet diameter, a capacity sufficient to suffer two boats to pass; over the pit a building must be erected, to cover and support the works; in the centre of which a drum-wheel of one diameter is placed. On each side of the drum, two chains and a cage to receive the boat is suspended; which cage will move alternately between the upper and lower canals; on the end of the upper canal, and on the side of the pit, there are two gates, balanced so as to rise perpendicular, as at A and B; and opposite the gates, parallel to the canal, two lock-carriages, C and D, worked by rack and pinion, moving on iron rails; which carriages are constructed with one end open, and of a size to receive the cage and boat.

When the lock-carriage is moved forwards, it fits close to the end of canal in a groove; and the gate being opened, the water of the canal fills the carriage; which enables the man to float his boat in the cage; after which, the gate being shut, and a valve

O

opened

opened in the hind part of the carriage, below C D, to discharge the water, the carriage is run back and leaves the boat suspended over the pit; during this operation, the man below having placed an empty boat in the lower cage, the two boats are now ready to pass; the loaded one descending, raising that which is empty; and at the same time, by a crank movement taken off the end of the drum, three pumps are put in motion; and they raise the water, which was discharged from the lock-carriage, into a *sider pond*, about twelve feet high, into the upper canal; by which the whole is saved. The empty boat having ascended, the second lock-carriage is run forward, and the gate of the canal being opened, the water filling the carriage, will float the boat into the upper canal; another for the purpose of descending, is then moved into the cage, and so on alternately.

To regulate this machine, the centrifugal fans are applied, as in the other apparatus; but the balance-chains will be of no consequence, as the loaded boat descending will be sufficient to raise the weight of pendent chain, if the depth is not more than one hundred feet, also work the pumps and raise the empty boat; four tons descending would also raise three, by casting the pumps out of gear, by the lever E, so that some alternate trade might be performed.

But should future extension produce an alternate trade, the pits and tubs may be added to this apparatus, converting it to a double machine; for a return trade, this machine would transfer two boats in about eight minutes; consequently, in the descending trade, about three hundred and sixty tons might descend, returning the empty boats, in twelve hours. In the alternate trade, twice the

the above quantity would be performed by raising loaded boats at the several movements.

Its expence for the descending trade, one hundred feet deep,	
about,	£. 2,500 0 0
For the alternate trade,	3,500 0 0
	6,000 0 0

Which is about half the expence of locks.

C H A P. XVII.

DESCRIPTION OF PLATE XII. REPRESENTING THE SECOND MODE OF PASSING THE ALTERNATE TRADE BY A PERPENDICULAR LIFT.

IN constructing this machine, the tunnel and two pits are similar to the first lift, and the drum-wheel of two diameters, which must be so placed, that one side may be over the centre of the pit; the cage chains being fixed to the large, and the tub to the small diameter.

One gate must then be placed on the end of the upper canal, as in the last machine; also one lock-carriage, moving parallel to the canal.

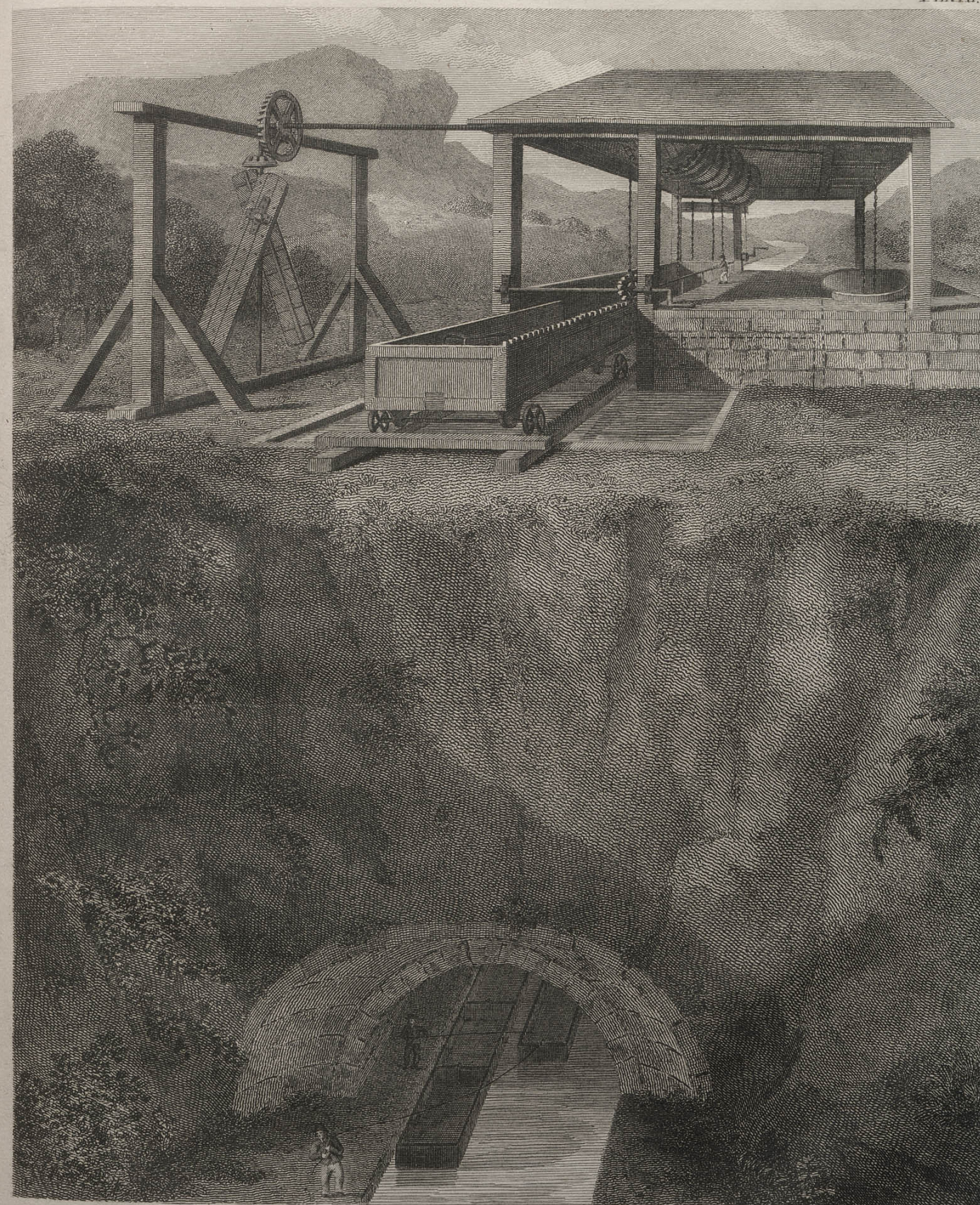
On the side of the machine, and below the hind end of the lock-carriage, a small pond is formed to receive the water discharged from the lock-carriage; which water is afterwards drawn into the tub, to create the preponderating power, and answer the double purpose of floating the boat into the cage, and then raising one from the bottom to the top canal.

To regulate the movement of this machine, the centrifugal fans are applied, as before described.

The expence of one hundred feet rise, about 2,500 l. and the execution near three hundred and sixty tons in twelve hours.

In these three machines, the quantity estimated being the work of twelve hours, it consequently may be doubled by working at night; which, I hope, exhibits that lateral cuts might have been extended to great advantage by these machines.

CHAP.



The Second mode of passing an alternate Trade.

London: Published by I & J. Taylor, Holborn, March 1796.

OF CAST-IRON RAIL ROADS.

RAIL-ROADS have hitherto been constructed as a medium between lock-canal and cartage; in consequence of the expence of extending the canal to the particular works in its neighbourhood.

But as the small boats so materially reduce the expence of canals, they come nearer to the expence of rail-roads, with which they must now be compared. The usual estimate of rail-roads is about 1,600 l. per mile, which are single, with passing places, and only calculated for a descending trade; the whole being formed of a gradual descent from the works to the canal; generally so calculated, that a horse may return the empty waggons with the same ease the full ones descend; on these the average work is about five tons to a horse, descending at the rate of three miles per hour, or one ton ascending, at near the same speed; on which the wear of waggons is very considerable; which wear must generally fall on the company; while the loading into waggons, then unloading at the canal, where there is usually a deposit for want of boats, and again, loading into boats, tends to increase the expence of conveyance, and injure the various articles.

There can no idea be formed of the expence of a canal compared with a rail-road, without being acquainted with the circumstances; but these should be well considered before a rail-way is laid down; and the canal should considerably surpass the expence of the rail-road, *particularly if the length is greater than two*

miles,

miles, in order to induce subscribers to relinquish it for a rail-way; and my reasons are, that when a rail-way is laid down, it excludes, in a great measure, the return trade, and shuts out the prospect of extension; the country, beyond its extremity, has no more hope of assistance, than before its construction; nor will any company unite with it; for if it is added to, the difficulties increase, as passing places are inadequate to an important trade; consequently, it would be necessary to form them double, increasing the expence and repairs; without the power of raising succours to the high and interior country.

Yet the small canal is sufficiently wide to pass at every part, and transfers a trade with equal ease; meandering the hills, it holds out assistance to the sun-burnt fields, and seems to invite connection: In a country, through which a rail-way or canal is constructed, there is some hope of progressive improvement and future extension; which ultimately brings this enquiry to two questions: Whether do canals, or rail-ways, present the best prospect of extension? And, Which will most facilitate conveyance by a union of branches?

It is therefore prudent to consider well the various circumstances, before a rail-way, of even one mile in length, is laid down.

Rail-ways of one mile, or thereabouts, will no doubt be frequently necessary, where it may be difficult to find water at the extremity; or when the trade from the works is not sufficient to pay the expence of machinery, and its extent being but one mile, can be of little importance to the country.

But

But to bring these short spaces into the general system as much as possible, see D, in the Plate of Parts: which represents the apparatus for returning the empty boats to the collieries, or other works, in cases where a regular descent can be obtained. Suppose, for instance, such works distant six hundred, or perhaps, more yards, a single rail-way may be constructed; on the summit of which the apparatus D is formed; and a carriage being constructed to receive the boat, the leading rope laps round the vertical wheel F; which wheel works by a multiplied movement in the wheel of the shaft G, to which a weight is suspended; on a loaded boat descending the rail-road, its power will wind up the weight; which weight is kept up by a stopper on the wheel, and is a power in reserve to draw up an empty boat; hence, when a loaded boat descends, it winds up the weight, and on entering the canal, the shaft of F and G are cast out of gear, which suffers the carriage to descend sufficiently to allow the boat to float: an empty boat is then placed in this carriage; and the stopper being cast off the wheel on the G shaft, the descending weight will raise the empty boat; the movement being regulated by a break, on the shaft of F there are two pinions of different diameters, which are, that the wheel F performs more revolutions in a boat ascending than descending. When the boat descends, raising the weight, she loses her power on entering the canal; consequently, the pinions must be cast out of gear in order to give more length of rope for the carriage to descend, and allow the boat to float; therefore, the portion of rope thus let off, must be wound up by the power of the weight, on returning the empty boat; which is done by casting the small diameter into gear. In the return movement, this mode of working will be found a very considerable saving to the proprietor, in consequence of a single plane and rope answering the purpose; and, in order that the plane may be

be constructed cheap, a carriage to receive the boat should be made; the carriage to have from ten to twenty small wheels, which will divide the weight on so many points, and ease the plane; consequently the rails may be light and cheap.

But where the nature of the ground will not admit of a regular plane, or the distance is too great, the boats may float on a carriage for the purpose, with six or eight wheels, and be conveyed to the pits or delphs by a horse; there take in her cargo, and descending to the canal, be immediately ready for navigation.

The reader, by reverting to the various operations these small boats pass through; many of which, *where the trade is great*, must be performed with the utmost expedition, from which the greatest part of the numerous advantages arise, I hope, will now see the necessity of their wheels; which, like a boat and waggon combined, has, in a great measure, the properties of both: or, like an amphibious animal, the double advantage of living in two elements. Therefore, if it is necessary to give them a name, in order to discriminate from other boats; *as small boats* do not divide the idea, in speaking of them, I have thought *Beavers* might be applicable.

CHAP.

C H A P. XIX.

ON CONCLUSION OF THE SMALL CANAL SYSTEM.

HAVING exhibited the various machines for transferring the small boats, and gone through the operations, in which I have endeavoured impartially to present the fair comparative view of the general effect of large and small boats; I shall now take a summary review of the whole process, the object in view, and the effect which ought to be produced by canals.

First, in the true sense of national improvement, to facilitate agriculture and merchandize, the whole ponderous carriage of a kingdom should, *as much as possible*, be conveyed by canals, thus reducing expence, opening easy communications, exchanging the produce of one district for another, improving the country, reducing the number of horses, rendering manual labour more productive, and spreading with greater regularity the comforts of life. Hence there should be a power of extending canals into every district, in order to draw from every source; but it is evident this can only be done by portioning the expence of the canal to the trade.

Yet, however desirable this may be, it cannot possibly be performed by lock canals; locks load a canal with certain and heavy expences which descend to one point, *for twenty-five ton boats*, below which there is no reduction, whatever the trade may chance to be: every country, therefore, which cannot produce a trade equal to those heavy expences, must be shut out from the benefit of water-carriage, and this is by much the greater part of the kingdom.

P

Wherever

Wherever the importance of two great trading towns, or commercial countries, can bear the expence of a lock canal, it may be constructed; but it is impossible to branch off into the less important or poor districts with large boats, which carry with them all their consequent expences: which is not only unmechanical, but impolitic, in two respects; it excludes the benefit of water conveyance to such districts, towns, and hamlets, and bars out a trade which ought to be drawn into the canal to the benefit of the proprietors.

But a small canal, forming a communication between two important counties, is so easy of access, in consequence of the small boats, that lateral cuts are easily constructed; they consequently will extend into the country, and others from them into every nook and corner where forty or fifty tons per day can be collected: thus the country will be nourished, as veins feed the constitution; and the canal become important, like a river receiving numerous streams: while another advantage of the small boats, that of moving flow and taking quantity, or conveying a less quantity and passing with the rapidity of a coach, *which will most materially accommodate merchandize and valuable articles*, will take in almost the whole ponderous carriage of the kingdom; which circumstance will draw immense quantities of trade on canals that must for ever be excluded on the lock principle. The canal being also cheap, and suited to a small trade, yet adequate to a trade of the first importance, consequently the boats of one may navigate the other wherever canals extend, persevering regularly throughout; while their cheap formation is the greatest possible inducement to their construction: I shall therefore bring this subject to a few questions, which I wish every speculator to apply to his own deliberations.

First,

First, As a small canal, *averaging the situations*, may be constructed for one half the sum which a canal for twenty-five ton boats would cost, or about one third the expence of one for forty-ton boats; Is it not better for a subscriber to have as good a prospect of receiving ten or fifteen *per cent.* by the small, as five by the greater work; yet, guarded against any material loss, have every advantage which the large canal could give?

Secondly, In constructing a navigation, is it not better to expend 33,000l. in a small canal, and have the prospect of drawing in numerous connections by the cheapness of the system, than to spend 66,000l. for twenty-five ton boats, or 100,000l. for forty-ton boats, in forming large canals, to accommodate a few unusual articles which the small boats cannot convey, and thereby prevent the possibility of lateral cuts; which would return infinitely more trade into the canal than the small boats exclude*?

Thirdly, Which will command the most trade, the small boats, by the cheapness with which they may be extended into every district where there is any thing to carry; or the large boats, by their capacity to contain unusual and bulky articles?

Fourthly, Or will the consequence of those unusually bulky commodities be put in competition with goods of medium dimensions: which are certainly ninety parts out of a hundred of the whole carriage of the kingdom?

Fifthly, In a national view, is it not better to have three hundred miles of canal for the same money which it now costs to make *one*

* I beg Gentlemen to consider what are the things which cannot be conveyed in boats twenty feet long, four feet wide, remembering my provision for timber.

or two hundred; and extend the conveniencies of water-carriage in a two or three-fold proportion?

Sixthly, If a company are about to expend 300,000*l.* in a canal for forty-ton boats, the canal only thirty miles long*, when ninety miles might be extended into populous districts for the same money; which, in common sense, would make the best return to the subscribers?

Seventhly, It is not a fair criterion to judge of the application of a small canal by these circumstances?

Eighthly, Is it not also fair, to compare the interest of the principal saved, by adopting the small, instead of the large boats, with the expence of transferring the cargoes from large to small boats; considering, that the transfer of cargo will fall on the freighter?

Ninthly, To view this subject to its extent, as of individual and national importance, will not the small boats draw infinitely more trade into the channels of canal conveyance, in consequence of their cheapness and expedition, than can ever possibly be done by the large and expensive mode of locks?

Tenthly, Will not this system draw almost the whole carriage of the kingdom on canals; the greater part of which must for ever be conveyed in wheel carriages, if the lock principle is pursued?

Let each speculator, or member of a committee, contemplate these questions, and consider the process; let them propose these questions to their engineers, and request an answer; and I have no doubt of discussion drawing the large boats out of the streams of

* This is the case in many canals, or nearly this sum.

preju-

prejudice, and launching them into the rivers, their natural and proper situation.

Having put the question to engineers, I conceive it necessary to be properly understood by them: for I really have as a great a desire to be in harmony with all men, as to harmonise the canal system.]

I do not therefore mean to call their abilities to account, by this question, or to find the least fault with the works they have constructed; the lock-canals, though limited in their extension, and imperfect in their principle, were not invented by them; they have but prosecuted the principle, as the best method hitherto known for general utility.

When a company of gentlemen with a canal, they apply to and give credit to the reputation of an engineer; he consequently acts to the best of his judgment, which judgment is usually formed on established customs; and which, in many instances, has been judiciously exerted. But if such a system of operation was invariably to be continued, there would be no more scientific improvement among men, than in a bed of oysters.

I therefore look upon it as a duty in every man, who has the least pretension to science, to investigate every plan, which has even the resemblance of improvement; and he is responsible to his employers, if he persists without passing his candid judgment; his judgment should also be put to the test, by opposing it to one well versed in the subject; and thus light would appear, as friction brings forth the sparks of latent fire.

I am

I am aware, this challenge to a fair discussion may be construed into self-importance in me, by opposing my opinion to all others: but be that as it may, I deem it indispensably necessary in all improvements of a public nature.

A man, unthinking, may turn up a tuft of earth, and find a vein of gold, which interest will urge him to pursue: I, by chance, stumbled on this subject, by turning over a news-paper, or, in all probability, I should never have thought of canals. I mention this to shew, that I do not arrogate to myself a great deal of the ingredient which is called Genius; but that some of the most useful discoveries is the produce of accident. I found the subject interesting, and I have had the pleasure, in prosecuting it, to find it worth pursuing. It has also been some satisfaction, that it appears of national importance: and, as I conceive, I have now removed the principal part of the rubbish (*except one strong strata of prejudice*), and got my machines ready to work, I lay the enterprise open to the inspection of all, in order that, if there is any intrinsic worth, it may be assayed; and, I have some hope, it will not all evaporate in fusion.

Therefore, I do think it most seriously important, for speculators and their engineers, to consider this subject well, before they bring their bills into parliament, or prosecute another canal. If the system is sound, the sooner it is adopted the better; if not, let it be buried in its own insignificance.

As I venerate liberality and the light of reason, I despise the pusillanimity of the individual, who, like a dark lantern, conceals the light he receives. Therefore, whether this is a gleam radiating from a brilliant reflector, or the pale glimmering of inflammable

flammable vapour, I am determined it shall not be confined; and my reason is, that many useful improvements sleep for ages, for want of the fire of energy in the projector, while the only mode of proving their utility, is to bring them to the test of discussion: I, therefore, feel myself quite ready to meet every objection to this system of small canals; and, for this purpose, I here call on engineers, or others, who think proper to answer the arguments in their favour.

If they cannot do this, I hold myself perfectly justifiable in criticising on the works of those men, who may hereafter either wilfully, or ignorantly, prosecute the lock principle, and draw their employers into the consequent errors: I will therefore, once more, revert to the comprehensive view of the subject, Which will draw the most trade into the channels of water-conveyance, large or small canals; and which consequently will produce the greatest benefit to society? It will therefore be a feeble subterfuge to attempt to evade the question, by saying, this may do for some canals, but not for ours.

Such a reply would also be impolitic, and exhibit a limited sense of the small system; for, as I have before hinted, I will now assign my reason why the small canals will ruin the large ones.

Which is, that when the small canals are well understood, they will become so numerous, and perform the work at such low tonnage, as to reduce the lock canals, or their emoluments, which is the same thing, to the utmost insignificance, by drawing off their trade, as lock canals now draw the trade out of rivers.

The proprietors of the lock canals, will then have little more than the bulky articles; and it will then be seen, what proportion they bear to those of medium dimensions.

To give some idea of this, I beg the proprietors of the Leeds and Liverpool, Lancaster, Rochdale, Grand Junction, Kennet and Avon, Ellesmere, and various other canals, for river or forty-ton boats*, to suppose a small canal running side by side, or to the same points; which small canal would carry all articles of medium dimensions for one-third which the proprietors of the large canal could afford; where then would be the object of transferring cargo?

The same tonnage which would produce five per cent. to the large canal, would be fifteen per cent. to the small company; and, as fifteen per cent. is a comfortable profit, they, for the sake of engrossing the trade, might continue to reduce the tonnage as the trade increased, which still retaining fifteen per cent. to the small company, would prevent the larger from ever rising above five. Thus the small canal would absolutely be a dictator to the larger work, and fix its emoluments, above which it could not arise; but might be reduced to less than two per cent. if competition or disputes arose, the small canal still receiving five per cent. The reader will now judge, whether I have ushered this opinion into the world without some reasons to support it: he will also consider, whether any man would subscribe to large canals, taking upon himself a part of the risque attendant on such heavy works, when he could not, at the utmost, receive more than five per cent.

From these considerations, it is also a natural conclusion, that the large canal companies will endeavour to prevent those small works interfering with their trade; and, in case of danger, fly to Parliament with bills of infinite restrictions. But, I hope, a wise

* Twenty-ton boats in like proportion.

Legislature

Legislature will see, that competition is the true polish of society; that to reduce the expence of public works, is to improve the nation, and will therefore take off many of the restrictions with which they are now shackled.

As far as my judgment extends on this point, I conceive, if Parliament guard landed and mill property, also the feeders to established canals, the relative effect which the trade of one may have on the other, should never be considered; if all restrictions of this kind were abolished, canal speculations would still find their level; and competition would reduce the expence of carriage, which is the real object of canals: competition always takes as little profit as it can afford, monopoly as much as it can draw out of the freighter; therefore competition should meet with every encouragement, restrictions should be as few as possible, and circulation as free as the air we breathe. Till this is the case, the nation never can receive the full benefit which ought to arise from water conveyance.

CHAP.

Legislation will be, that competition is the true policy of society; that to reduce the expense of public works, is to improve the nation, and will therefore of the restrictions which they are now shackled.

C H A P. XX.

PLATE XIII. REPRESENTS AN AQUEDUCT OF CAST IRON.

IN constructing an aqueduct by this means, the buttments and piers being raised, it will only be necessary to extend two pieces of timber across the span; each to be braced back to the piers, and covered with plank to form a stage or scaffolding; which will answer every purpose of centres necessary to works of stone.

The iron-work, as in the section, may all be cast in open sand, and of the following dimensions; supposing the span one hundred feet, and the spring one sixth of the span.

First, Three segments of a circle, each in three pieces, about thirty-six feet long, eight inches by four diameter, to be united as at A. Second, three strait bars, to extend from one pier to the other, to be of the above diameters, may also be cast in three pieces; which bars are to extend along the top of the segments to the piers, and form a line parallel to the horizon; the bars and segments to be united by perpendicular stirrups, like B, ten or fifteen feet distant from each other.

The mortise in the lower end of the stirrup being thirteen inches long, will be sufficient to receive the segment, and leave room for a hole two inches square; through which a cross-brace, C, is to pass, and fasten the segments at proper distances; the brace to have



Fig. 1.

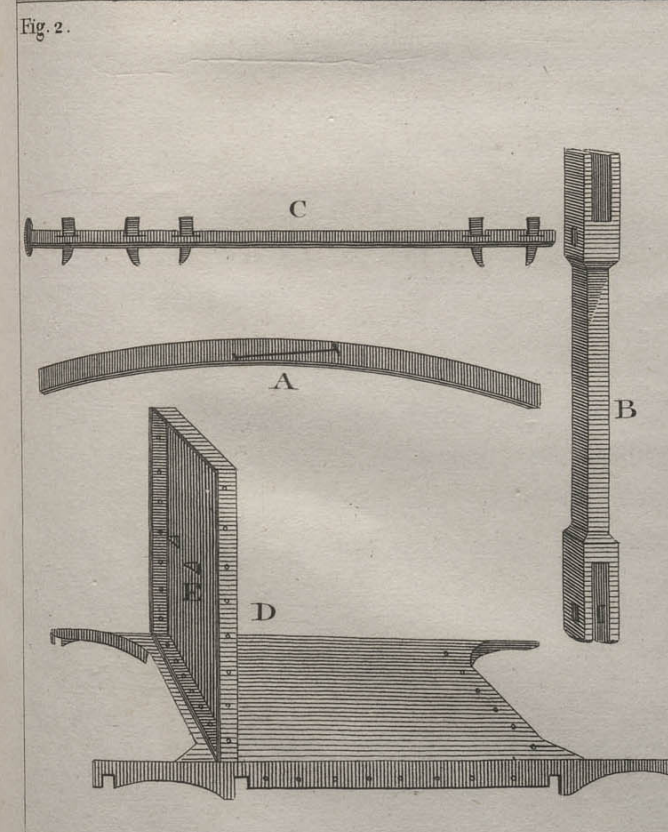
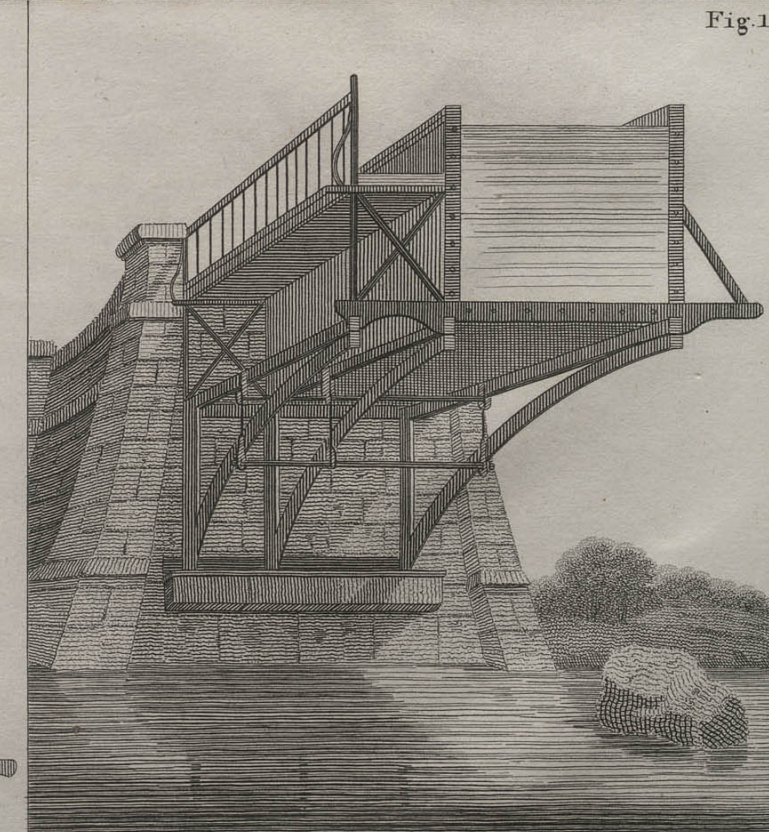


Fig. 2.



R. Fulton, inven. et delin.

An Iron Aqueduct Scale $\frac{1}{2}$ Inch to 100 Feet.

Fig. 1. Section, $\frac{1}{2}$ Inch to 6 Feet. — Fig. 2. Parts, $\frac{1}{2}$ Inch to 4 Feet.

London: Published by I & J. Taylor, Holborn, March 1. 1796.

have a mortise cast on each side of the stirrup, in order to tighten the work by wedges.

On the top of the stirrup, the square hole to receive the cross-brace may be beneath the mortise, as in the Figure; by which means, the whole may be combined and form an iron stage to support the troughs.

The trough plates should be at least one inch thick, the side plates six feet broad, and as great a length as can conveniently be cast; which may be performed twelve feet, and perhaps more, in length: the flange to be outside on these plates.

The bottom plates may be six feet wide, thirteen feet long, seven feet plate, and four arms projecting, each three feet long, in order to support the horse-path and braces; as exhibited by a bottom and side-plate at D.

Two of these plates laid across the stage, and screwed together, with the flange under, will compose a length equal to one of the side-plates; which may either meet or break joint as is thought proper. The whole may, in this manner, be screwed together, on packing of wool and tar; and have the seams pitched like those of a ship.

On the plates composing one side of the trough, small brackets, about three feet from the top, must be cast, as at E, in order to support the horse-path; perpendicular rails, eight feet long, being raised from the arms of the bottom plates, will support the outside of the horse-path, also the iron railing, as in the section.

By this mode, two patterns will answer for the whole of the trough-plates, and but few will be required for the springs, rails, and spurs; while the saving in time and expence will be considerable; particularly where it is necessary to bring the stone by long land-carriage; for the arches being dispensed with, and the piers not more than one-third the dimensions necessary to an aqueduct of stone, will most materially reduce the quantity of masonry.

But, according to the various circumstances of situation, carriage of stone, iron, &c. the disparity between the two modes will be easily determined, added to which, the durability may be of some importance.

In aqueducts of stone, one of the great difficulties is to line and puddle so tight, as to prevent the water penetrating into, and injuring the masonry; but in one of iron, should a leak take place, it will instantly appear; and on shutting the stop-gates at each end, and discharging the water, it may be stopped in a few hours, if not minutes: this circumstance, in aqueducts, is, perhaps, one of the greatest preservatives; they are consequently less liable to injury, and only subject to the corroding tooth of time.

CHAP.

C H A P. XXI.

ON BRIDGES.

THOUGHTS on aqueducts, and their construction of iron, bear so near a relation to bridges, that the ideas naturally tend to that subject, and hence I am led to offer some drawings on their formation of iron and wood.

In this country the attention of engineers, of late years, have been much engaged in bridges of iron, which bridges are progressively expanding as experience produces courage; nor should I be surprised, if genius in time gave the mechanic rainbow of one thousand feet to wide and rapid rivers.

In such countries as Russia and America, an extensive arch seems to be a consideration of the first importance: in crossing their rivers, as the rivers, or even rivulets, in time of rain suddenly swell to a great height, and in the Spring, on breaking up of the ice, the immense quantities which is borne down with a rapid stream would, if interrupted by small arches and piers, collect to such a weight as ultimately to bear away the whole; it is therefore necessary that one arch should be extended as far as possible, in such situations, and so high as to suffer every thing to pass through; or the inhabitants must, without some other expedient, submit their passage to the casualties of the weather.

The most extensive span of wooden bridges, as far as I am acquainted with the subject, are those of Schaffhausen and Wettingen, in

in Switzerland: the first, constructed over the Rhine, is formed in two spans, one of one hundred and seventy-two feet, the other one hundred and ninety-three, amounting to three hundred and sixty-five, supported by one pier, relative to which there has been numerous arguments.

The pier being the remains of an old bridge, and the artist having expressed his desire to cross the river in one span, or arch; but being over-ruled by the magistrates, who ordered him to give it a bearing on the pier, it is said he seemingly complied with their injunctions, but so contrived that no part should actually touch the pier; yet the pier is not in a line with the buttresses, but out of the rectilineal direction eight feet, forming an obtuse angle; and this circumstance is sufficient to convince me, that it must rest on the pier; therefore the greatest arch cannot be considered more than one hundred and ninety-three feet; yet certainly a considerable stretch of genius, and a strong instance of the curious fabric in which she frequently resides, the artist, Ubrick Grubenman, being a common carpenter, without the least knowledge of the principles of mechanics.

In a drawing which I have seen, the leading beam, composed of two pieces laid on each other, rises in a spring of about twenty feet over the pier, similar to the principles of a roof, and braced by perpendiculars and diagonals, in order that it may preserve its position, so that in some degree it operates like an arch, although in appearance the framing resembles a right line, the whole being roofed; a man on foot crossing this bridge will feel the whole fabric tremble, yet it is sufficient to support waggons heavily loaded, and bears every hardship usual to bridges.

The

The bridge of Wittengen, over the Limmat, is a span of two hundred and forty feet, raised about twenty feet from the water, and may be said to hang between two bows, the system by which it is supported being a strong bow or arch composed of eight timbers bolted on each other to create breadth, and back up against the weight, one of the bows being on each side, forming a spring of about twenty-five feet; the horse road is suspended between the two near the centre of the bend, this is also roofed, and by the mode of combining, has more simplicity and true mechanism than that of Schaffhausen, although constructed by the same self-taught artist.

CHAP.

C H A P. XXII.

PLATE XIV. ON BRIDGES OF IRON.

ALTHOUGH various have been, and are, the opinions relative to the construction of bridges of iron and wood; each artist seems necessitated to resort to something like an arch, but differing in their mode of producing it: they frequently create labour and expence by erecting a complicated fabric.

But, on this head, I conceive the first care is to have sufficient buttments; after which, let each segment of a circle, composing a rib, be formed of single pieces as long as can conveniently be cast; and it is evident, a circle must be compressed into a straight line, or the buttments separate before the bridge can come down.

It is therefore only necessary to form a segment, so that it may not change its position, by sinking in one part and rising in another, by the various weights which it may have to support, also guard against yielding side-ways; for this purpose, the great quantity of iron or wood is not so material as a judicious arrangement of the parts.

In iron, or wood, the artist may be furnished with pieces of greater length than possibly can be obtained of stone; consequently, there will not be such numerous joinings; and thus the span may be further extended: on which see Fig. I.

This

Fig. 1.

Fig. 2.

Fig. 3.

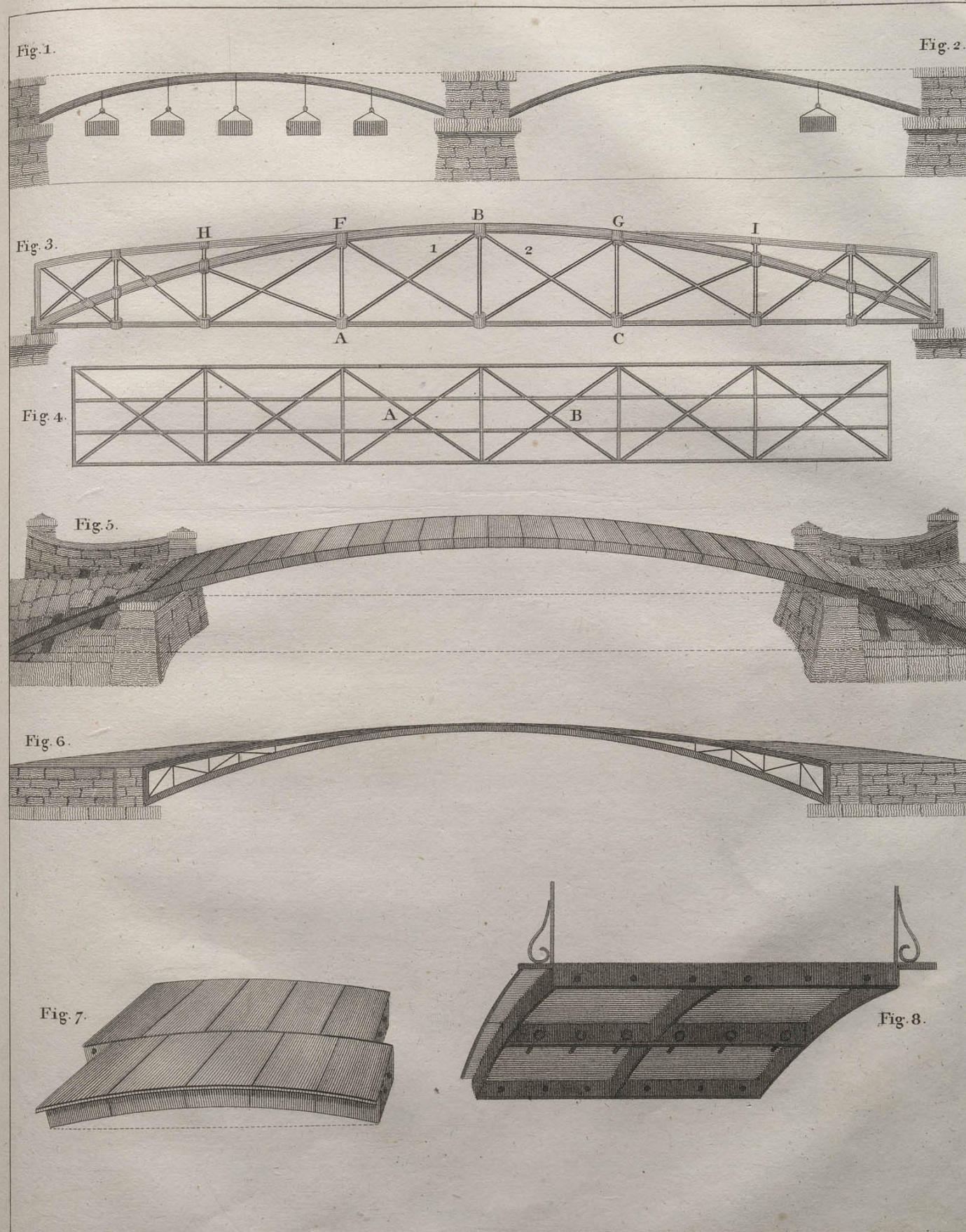
Fig. 4.

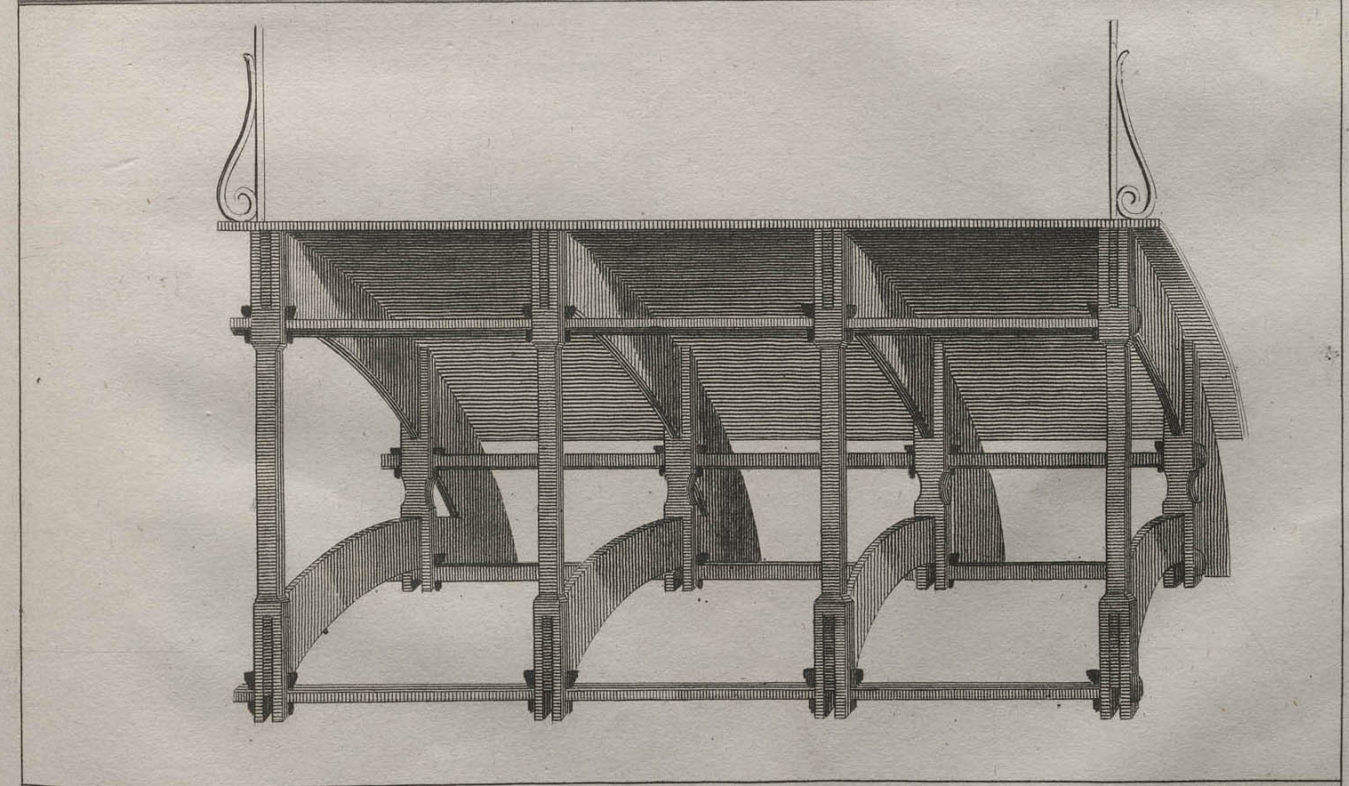
Fig. 5.

Fig. 6.

Fig. 7.

Fig. 8.





R. Fulton, inven. et delin.

*Design for an Iron Bridge Scale 1 Inch to 10 Feet.
The Section Shows the Ribs and Braces Scale 1 Inch to 4 Feet.*

London: Published by J. & J. Taylor, Holborn March 1. 1796.

Part of a Bridge composed of Iron Staves.

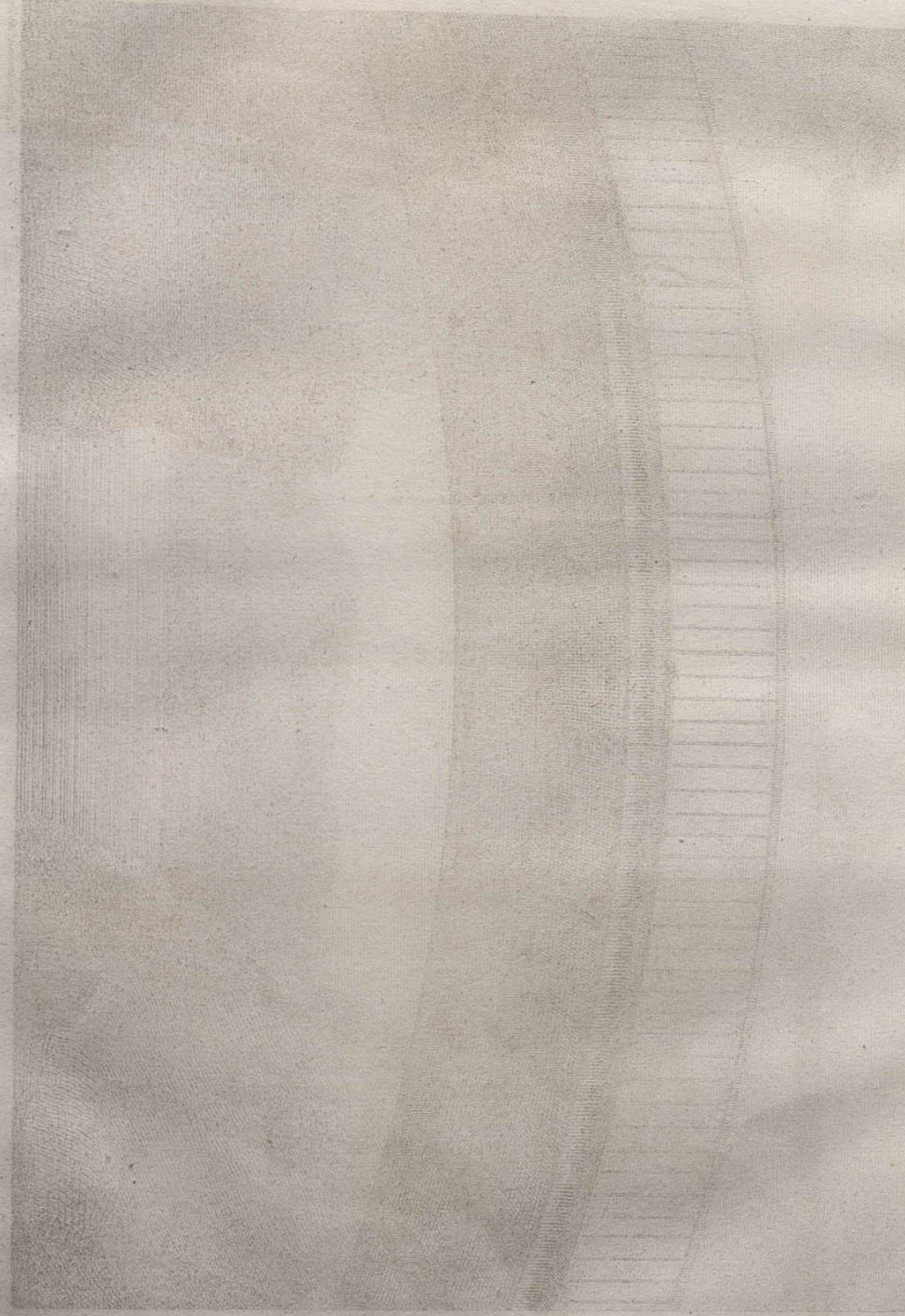


PLATE 16

PLATE 16



Part of a Bridge composed of Iron Staves.

London. Published by J. & J. Taylor, Holborn March 1. 1796.

This represents a segment of iron sixty feet long, eight inches broad by four thick, and may be considered as a single stone of that length; which being placed between butments and the spring, preserved in a perpendicular direction, let five weights be suspended at equal distance; and, in all probability, though each weight amounted to twenty tons, it would support the whole five equal to one hundred tons: yet, let one weight of twenty tons be suspended between the centre and end, as in Fig. II. and it is reasonable to suppose, the whole would come to the ground, as the weight would compress one part and raise the other, destroying the shape of the segment, and preventing the direct longitudinal pressure of the parts on each other, for want of counter-weights to preserve the equilibrium. Therefore, after forming a segment, the great point is to dispose of the braces, so as to divide the weights equally on the curve.

To effect this, Fig. III. represents a span of one hundred and thirty feet, by a scale of one inch to twenty feet; and is an arrangement of parts which, I conceive, would stand without butments, this may be considered as a bow and string; which string, by keeping the bow bent, answers the purpose of butments; all the other braces being for the purpose of preserving the bow and string in their proper situation, by dividing the weight on the bow. For instance, a weight over the perpendicular B, will tend to extend 1, and 2; in which case, they pass on A and C, and they pull down the bow at F and G; F and G, by the same system, pull down H and I, and so on, wherever the weight is placed its pressure will be divided along the bow, which consequently cannot vary its position: according to the width of the bridge required, four or more of such ribs must be constructed and placed perhaps ten feet distant from each other; the whole being fastened by

R

cross-

cross-bars passing through the stirrups, as in the aqueduct, and prevented from yielding sideways, by the diagonal braces exhibited at A, B, &c. Fig. IV. After which, the whole may be covered with plates of iron, soiled and gravelled, or planked, and covered with earth and gravel in like manner.

Although, I conceive, there is little doubt but a bridge, as above described, would stand to the length of two or three hundred feet, yet the multiplicity of pieces of which it is composed, in order to preserve the shape of the segment and relieve the butments, would evidently occasion much labour and nicety of workmanship; therefore it exhibits the importance of simplifying such works, in order to facilitate their formation, and apply every particle of materials, so that they may tend to strengthen the whole, and not be liable to alter the position.

I shall therefore return to the first proposal of adequate butments, to resist the longitudinal pressure of an arch of any dimensions. In this it must be considered, that the butments need not be of the immense size which first strikes the imagination; for whatever dimensions an arch of iron or wood may be, the quantity of materials is easily calculated, and the weight which the butments will have to resist; for instance, if an arch weighs five hundred tons, and the butments opposed to its pressure weighs one thousand tons, they consequently cannot move, not to mention the weight of earth backing, which tends to render them more permanent; therefore, seeing that the foundations are secured, and the springs, if any, well drained, in order to keep them dry, I see no difficulty in constructing butments to support an arch of any dimensions, and that at much less expence than butments and piers could be erected for a stone bridge; in the same situation particularly,

larly, if such piers were to be built in water of any considerable depth.

Having premised the butments to be of sufficient strength, I consider the arch, whether it be composed of iron or wood, to be like the segment of a hoghead, and the component parts as near as possible like the staves: for this purpose, in constructing one of iron, Fig. VIII. represents two staves, each of which might be cast in open sand, four feet broad from twelve to fifteen feet long, the pattern being formed to the radius of the spring, a flange on the lower side of the staff should be cast, about one foot broad, with holes to receive the screw pins; across the staff one or more ribs, if thought necessary, should be cast, to give strength to the top plate; these ribs and flanges, in uniting the staves would butt on each other, and ultimately compose a rib to the whole extent of the bridge.

Having cast the staves as wide and long as experience may hereafter prove expedient, I will suppose it necessary to erect a bridge one hundred feet span, as in Fig. V.; in building the butments, it would be adviseable to place two or three segments, of the same radius, as the bridge, in each butment, they being cast with arms, or united to binders, in order to take a firm hold on the masonry, and become a permanent support; the segment thus passing into the butments, might be considered as a part of the arch, which, by this means, would butt against the centre of the whole weight of the butment, and must push the whole away before the arch could yield; but, without this precaution, the arch would rest so near the top of the butment, as to raise the stone-work and endanger the whole. Having thus prepared the butments, a centre of three or more segments, so that each staff may have two bearings, should be

erected; and the staves being ready, all of one dimension, and the screw-pins all of a size, the arch might be sprung in a few days, breaking joint, as in Fig. VII. Thus each flange and rib would butt upon its neighbour, and the screw-pins confining the whole, it would become like one solid segment of a cylinder one foot thick, *extending into the piers.*

By this mode, the difficulties which arise in fitting diagonal, perpendicular and lateral braces, are avoided, the top plate performing the office of all such braces; which top-plates, in other compositions, have no tendency to strengthen: thus every particle is applied to resistance, and the materials have but few joinings; which junctions have also broad and permanent bearings of one foot on each other, the flange and ribs being cast of that depth. Thus, I conceive, a bridge of one hundred feet, or perhaps one hundred and fifty feet span, might be erected at a cheap rate, with a small quantity of materials, yet with the prospect of great durability. If I suppose a bridge one hundred feet span, thirty wide, with the top plate one inch thick, five flanges or ribs, each one foot broad and two inches thick, the whole weight of the arch would not be more than seventy-eight tons, allowing one pound to every four cube inches of cast-iron.

So far relates to iron bridges of one hundred or one hundred and fifty feet span; but should it be necessary to extend them to a greater length, to say three hundred feet, two segments would then be requisite; the first, as in Fig. VI. as the principal support; the second, to ease the passage, should be of such a bend as would admit an easy ascent and descent; and, by being part of a curve, it also tends to strengthen; thus, if I say, span three hundred feet, the first spring thirty, the second spring only ten feet, they both must be

be compressed into freight lines, before they can come down; they will also have twenty perpendicular feet of bearing on the butment, the bearings opposite to the two segments being opposed by segments entering the butments, as before described; the two segments must be kept asunder by perpendiculars in the haunches, placed at about ten feet distance from each other, as in the Figure. See Plate XV. exhibiting the combination by ribs and braces; also Plate XVI. representing the arch of staves.

Having exhibited the mode of construction, I conceive it unnecessary to comment on the particular formation, or to draw a comparative view of this and other bridges of iron; as in cases where they may be required; the artist will weigh the various circumstances, investigate the several modes of building, and choose for himself; in which there is a leading deliberation, viz. By what means can a given quantity of materials be arranged, so as to incur the least expence in erecting, and be rendered most permanent; and by which mode will the least materials answer the purpose?

Very good

C H A P. XXII.

PLATE XVII. OF BRIDGES OF WOOD.

THE important objection to bridges of wood, is their rapid decay: and this objection is certainly well founded, when particular situations are alluded to, where timber is scarce, and consequently expensive; but in such countries as America, where wood is abundant, I conceive it will be a fair criterion to judge of their application, by calculating on the expence of a bridge of stone and one of wood; then compare the interest of the principal saved in adopting the wood-bridge, with the expence of its annual repairs.

I have before exhibited the necessity of constructing bridges in America, of an extensive span or arch, in order to suffer the ice and collected waters to pass without interruption: and for this purpose, it must be observed, that a wood arch may be formed of a much greater length, or span, than it is possible to erect one of stone; hence they are applicable to many situations, where accumulated waters, bearing down trees and fields of ice, would brush a bridge of stone from its foundation.

It therefore becomes of importance, to render bridges of wood as permanent as the nature of the material will admit.

Hitherto the immense quantity of mortising and tennants, *tenants* which however well done, will admit air and wet, consequently tend to expedite the decay of the weak parts, has been a material



Design for a Bridge of Wood, Scale 1 Inch to 50 feet. With the mode of Combining the Timbers.

London: Published by T. & J. Taylor, Holborn March 1. 1796.

error in constructing bridges of wood; the mode of arranging the parts, by a repetition of bracing, has also exposed almost every side of the whole of the timbers to the changes of the weather; consequently, the whole was reduced to the durability of one stick, similar to suspending a cage in open air, each stick is exposed to decay, without receiving shelter from each other.

It has also been usual to place supporters in the water, subjecting them to the surge of floods, which shake the whole fabric; which supporters decaying progressively let down the upper works.

But to render wood-bridges of much more importance than they have hitherto been considered; first, from their extensive span; second, by their durability; two things must be considered: *first*, that the wood-works should stand clear of the stream, in every part, by which it never would have any other weight to sustain than that of the usual carriage; *second*, that it be so combined as to exclude as much as possible the air and rain.

For this purpose, in erecting a bridge of wood, I would proceed much on the same system as in constructing the one of iron staves. For instance, suppose a bridge three hundred feet span, thirty feet wide, the butments being rendered secure, and centres raised on piles; let timbers, if convenient, be procured thirty feet long, and of as great diameter as the country will produce; such timbers being squared and planed to the radius of the arch, with the holes to receive a bolt or trundle, about four feet distant from each other; the whole operation in springing the arch, will be to tar or paint the junctions with white lead, and insert the trundle, as at A, Fig. II. and press them close, thus lay them side by side, by which means an arch might be laid in a few days,

days, and as soon as the last timber is placed, the centres may be removed, and each piece pressing on its neighbour, will tend to render the whole compact; this being done, bolt down the belts C and D, distant from each other, in a lateral direction, about ten feet; then cover the whole with old sail-cloth, or tarpawling, tar, and sand; of the tar and sand, two or three coats may be laid on, which will fill every apperture, and form a permanent cover to the total exclusion of the air and rain. The arch being thus covered and kept dry, would present a segment of a cylinder, at least one foot thick, guarded from the change of seasons, and in all probability would last many ages. The first segment being formed, proceed to raise the perpendiculars off the belts to support the second or upper segment; which segment should be coated in like manner with tar, &c. previous to laying on the earth and gravel; which earth and gravel should be, perhaps, eighteen inches thick, in order that wheels might never wear to the timbers or coating. Having described the construction, and exhibited the formation, by the engraving, it is but necessary to observe, that the staves composing the arch are not eat away by mortising, but preserve their whole strength; thus being joined like staves, two sides only of each stick is exposed, which being coated, the whole of the timber is completely covered from the weather. I will now leave my reader to reflect on the strength and durability of this arrangement; and then proceed to consider to what extent of span such bridges may be constructed.

In this I must call to mind my former remarks, that the segment of a circle must be compressed into a strait line, or sink in one part and rise in another, or the buttments separate before it is possible for a bridge to fall; by longitudinal pressure, the lateral tendency shall hereafter be observed, admitting the above proportions,

tions; the question is, Whether the arrangement of parts is so calculated as to guard against such accidents? which probably will appear by the following considerations:

First, the buttments may be made to resist any weight, by giving a greater weight of stone than there is weight of materials in the arch*.

Second, the timbers being laid side by side, like staves, and pressing on each other, leave not the least aperture into which the parts of mortised and framed timbers might be compressed; hence, several timbers, in a long arch, must absolutely be compressed into nothing, before the segment could become a strait line.

Third, that it may not vary its position, by sinking in one part and rising in another, with the various weights, I will consider the staves and belts only: it must be observed, that by bolting down the belts, which belts may be from thirty to forty feet long, and break joint, as in Fig. II. the whole arch will become like one solid piece of timber, bent between the piers. I will now suppose such a bridge forty feet broad, the timbers combined eighteen inches thick; hence, admitting that it was constructed of wood as light as fir, each lineal foot would weigh one ton and a half, hence every thirty feet forward would weigh forty-five tons; as a waggon, when loaded, seldom weighs more than five tons†.

* Although this may not be necessary, it is certain; and as it is more my intention to exhibit the possibility of constructing bridges of a great span, than to point out the precise proportion of the parts, I conceive, by shewing it possible, future deliberations of ingenious men will determine the proportion.

† By this I mean the broad-wheeled waggon of England, the American waggon is seldom more than three tons.

And admitting four such waggons, weighing twenty tons, to stand abreast on the bridge, in which situation they would have the greatest possible pressure, by acting near the same spot; yet, to compress the part, thirty feet of the bridge, at least, on each side, must rise, and this in some measure raising the whole of the spring, which would be a weight of at least one hundred tons; hence, as twenty tons cannot move one hundred, without superior leverage, and as there is no leverage obtained, consequently there is no weight which it is reasonable to suppose can come on a bridge at one time can injure it.

The longitudinal pressure being considered, the tendency to yield sideways may be prevented, by constructing it wide at the ends and contracted in the centre; the pressure will then be resisted by an arch in every direction. Having exhibited the construction, and assigned my reasons for its permanency, I hope it will easily be admitted, that a bridge of three hundred feet would be perfectly safe; but if the reader should hesitate at this, he has my reason why it would stand, and it will be well to discover the reason why it would not: but supposing it admitted, that three hundred feet would be safe, I see no difference between that and one of five hundred, or even more feet span, the proportions being preserved by a spring one tenth of the span*.

* When the true principle of building bridges of wood is discovered, their progressive extension is as reasonable, as the increased dimensions of shipping; which, in early ages, was deemed a great work if they amounted to one hundred tons burthen; but time and experience has extended the art of ship-building to two thousand tons; and in the combination and arrangement of the various and complicated parts, there certainly is more genius and labour required than in erecting a bridge of five hundred or one thousand feet span: but the great demand for shipping has rendered the formation familiar, and their increased bulk gradually grew into the senses: but had a man, in the infancy of naval architecture, hinted at a vessel of two thousand tons, I am inclined to think his cotemporary artists would fix him with the gentle appellation of mad-man.

Having made this assertion, I almost fear I have forfeited the confidence of my reader, who may now be inclined to doubt the stability of my senses; but patience should accompany investigation, and I must beg of him to proceed to give some idea of the proportion of such a bridge of five hundred feet span, fifty feet spring, and forty feet broad: take a board eleven feet long, ten inches wide, and half-inch thick, and bend it between two blocks till it rises twelve inches, and it will give a model of the spring of an arch composed of two rows of staves, each a foot thick, amounting to two feet in thickness; extend this idea, by measuring off five hundred feet in a field, and imagining a perpendicular in the centre fifty feet high, then draw a segment by the eye, conceive the whole well wedged and bolted together, the proportions of the timbers preserved, and deliberate on the part where it could give way.

TO

THOMAS MIFFLIN,

GOVERNOR OF THE COMMONWEALTH OF PENNSYLVANIA.

SIR,

DURING the prosecution of my experiments on Canal operations, which are exhibited in the preceding treatise, I frequently contemplated their great importance to the States of America, and much wished to awaken the public mind to a full sense of the subject; but, on considering the habits of the people of the interior country, accustomed only to land carriage, I feared much difficulty would arise in removing the prejudice in favour of waggoning, and in raising a sum of money adequate to the first expence of a canal of importance. In deliberating on the mode of surmounting these obstacles, I was so fortunate as to meet with your Address to the House of Representatives in 1795, and particularly happy to find your ideas, of the importance of easy communications between remote parts of the country, so consonant to my own, and at the same time so earnestly recommended to the public attention: which circumstance has urged me to address this Chapter to you, convinced that your sense of the subject will not suffer any observations which may be useful to lie dormant.

I must therefore request you deliberately to peruse the system laid down, which you will find, by Chapter VII. totally explodes the old practice, for two reasons: *First*, Because they may be constructed for half the sum necessary to a lock canal; and, *Secondly*, Because on them you may perform dispatch, and pass through the most mountainous country at the speed of six miles per hour; an advantage

advantage which lock canals can never give, and which precludes an immensity of carriage: yet the small canal takes in every kind of conveyance, and performs the double office of a canal and road; therefore, if founded and governed by sound principles, a mountainous country may have all the blessings of water conveyance, so celebrated in the level and fertile plains of Egypt. But how to extend these conveniencies into every corner and district of America, is now to be considered.

While the mind hovers over the immense continent of America, and views its vast interior, inhabited in various districts remote from the marts of trade, with infinite scenes for the improvement and nourishment of millions of human beings, philanthropy seeks to combine the exertions of the present inhabitants to facilitate their labour, extend their interests, invite population, and give a cultivating hand to every acre of that extensive territory.

To such a wish, in one point of view, is presented a great and fertile country, interspersed with luxuriant vales and numerous mountains, nourishing infinite rivulets, which, meandering the country, feed long and rugged rivers, diminishing to naked shoals in dry seasons, or swelling to roaring torrents in time of rain; pressing their way through stupendous cliffs and infinite rocks, present objects hostile to navigating the streams of nature.

But such are the materials which art must bring into unison; the performance of which is a subject the most benevolent and important, and worthy the serious contemplation of the penetrating members of society, as a great national question.

On this head it must be evident, that in proportion as produce is remote from market its value is diminished, in consequence of the

the expence of carriage, and hence remote parts are excluded the market, or a facility of exchanging their surplus produce for necessities which they may require; thus the nerves of exertion are cramped, the faculties of body and mind are not called forth, and the country remains a dreary and inhospitable waste. But to encourage population and increase the value of the lands, the cheapest possible conveyance of the produce must be established on sound principles; for, exactly in proportion to the ease of reaching the market, the remote countries of equal fertility will be of more or less consequence in the scale of society; therefore, to sum up the idea, would not the lands about Fort-Pit be as valuable as those round Lancaster, if the produce could be brought to market for the same sum; and would not population consequently be encouraged?

For this purpose, as I have the strongest conviction operating on my mind, that canals are the only effectual means of producing easy communications, and that they consequently are of the utmost importance; I much wish that the public may be made thoroughly sensible of their utility, and that each State might establish a society to investigate the propriety of forming them in such districts as the present state of population and trade may most require them; keeping one important object in view, that all future canals may be constructed on one scale and principle, in order that when the various branches meet the boats, one may navigate the other wherever canals extend. This you will observe has been my wish throughout, and in which I hope I have been so fortunate as to succeed; if so, canals appear in a new light, and are still more important than formerly, because they may now be fitted to every kind of country, and by their cheapness approach near to the expence of constructing turnpike roads.

At

At a period when a country is improving by turnpike roads, the question is, whether it is not best to adopt canals; and the criterion to judge of the propriety of the canal, will depend on simple calculation, to the following effect; *1st*, what is the expence of the road; *2^d*, what is the expence of the canal; *3^d*, what is the expence of carriage by the road; *4th*, what is the expence of carriage by the canal; and probably it will be found the canal will perform the work so cheap, as to justify three or four times the sum being expended in the canal, that would be necessary to constructing a road of the same length; to which one consideration must be added in favour of the canal, viz. on all roads, however good, the great expence of carriage is the number of horses; but on canals, the principal expence is the tonnage or tolls to the proprietors, as interest for the money advanced in forming the canal: yet this tonnage by a judicious arrangement may be reduced, *if not liquidated*, and the carriage on a canal may be so regulated, that goods conveyed four hundred or more miles, will not cost more than those which are navigated eighty or one hundred miles; yet the eighty or one hundred miles canal conveyance will not cost half the sum necessary to land carriage, on the best of roads.

To elucidate this, I will suppose a canal from Philadelphia to Fort-Pit, or any other long line, to say, three hundred and fifty miles; on such a canal a man, boy, and horse, would convey forty tons twenty miles per day, and arrive at Philadelphia in (*say*) eighteen days, at 10s. per day, amounting to 180 shillings for forty tons, or 4s. 6d. per ton, the expence of boating, independent of tolls. By a road of the same length, four horses, perhaps five, would set out with not more than two tons, and, travelling at the rate of twenty-five miles per day, arrive at Philadelphia in fourteen days; and to say only two dollars, or 15s. per day, amounting to 210 shillings, or 5l. 5s. per ton for waggoning, independent of turnpike.

pike. This, I hope, will exhibit the immense disparity between the two modes, and shew that roads, however good, can never effectually relieve a remote country. The question then is, how to construct a canal in order to reduce the tolls, and completely assist the distant districts; this I conceive will totally depend on the mode of raising and appropriating a sum of money to the first fifty or one hundred miles of canal.

In this country, canals are paid by companies of subscribers, who receive a toll on the carriage of goods as an interest for the money advanced, and the immense quantity of carriage throughout every part of this compact kingdom, usually produces a considerable interest for the money expended, while the expence of carriage is reduced below that of land conveyance; but as England is environed with water, with numerous sea ports, there is no part very remote from the market, and hence, they never will have canals of any comparative length with those necessary in America, to say seven or eight hundred miles; therefore the mode of proprietors receiving tonnage at so much per mile, although it will ever be much below land carriage, yet even that tonnage would preclude the market from the remote country, and by no means answer for American canals: for instance,

	£.	s.	d.
A constructs a canal fifty miles long, and receives two-pence per ton per mile	-	0	8 4
B ditto	-	0	8 4
C ditto	-	0	8 4
D ditto	-	0	8 4
E ditto	-	0	8 4
F ditto	-	0	8 4
G ditto	-	0	8 4
350 miles	£. 2	18	4 per ton, tolls,

tolls, independent of boating; and hence I conceive the produce could not bear the expence of carriage by this method.

But as it is the produce of the interior country which must be drawn forth, the leading canals should be national works, perhaps by the following system.

First, That the legislature, by such duties or imposts as they conceive most eligible, raise a sum of money adequate to the expence of the first sixty or seventy miles of canal; to say from Philadelphia to Lancaster, which perhaps may cost 150,000l. of which 30,000l. per annum, may be required till the canal is finished. On this canal, sixty miles long, if I suppose fifty tons per day to be navigated at two-pence per ton per mile, allowing two hundred and eighty working days per year, it would amount to 7,000l. per annum, which should be applied to extending the canal; the tolls on such extension being appropriated in like manner to further extension, and so on, the toll to be continually devoted to forming more canal; till canals would pervade the whole country by virtue of their own produce arising from the tolls.

If this mode of extending the canal, by appropriating the tolls, should be deemed too tedious for the speedy relief to the interior country, and the funds of the state would admit of the advance of a further sum, they might immediately extend the canal two hundred miles, and receive the tolls, till the last advanced sum was liquidated; or, as the proprietors of the lands in the interior would be much benefited by their property being raised in value, probably they might raise the sum, and receive the tolls till such sum was liquidated: the lands being increased in value, might be deemed

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sufficient interest till the principal was discharged, which would diminish every year.

If by either of these modes, or any better which can be devised, I suppose the first two hundred miles of canal to be formed, the trade will be more in proportion to the length than on the first sixty miles before estimated; because, being more remote from the metropolis, the interior inhabitants will be necessitated to fly to the canal, the tonnage will also be greater; therefore, if I allow on the two hundred miles one hundred tons per day, to be navigated at twenty shillings per ton for the whole length, or in proportion for a shorter distance, the annual produce would be 28,000*l.*; and having arrived at such annual income, canals would proceed with dispatch, and progressively increase, both in riches and extension; each year the produce of tonnage would increase, and each year a greater length of canal might be constructed.

Therefore, if I proceed with this progressive and creative system, till a canal reached Fort-Pit, which, with some bends, I will call three hundred and sixty miles; the country, which such canal would accommodate, would widen as it was more remote from Philadelphia. For instance, the man who lived twenty miles from Philadelphia, might convey his goods seven to the canal; the man at forty miles distance might go fourteen or fifteen to the canal; at sixty miles, twenty to the canal; and so on, till at the extremity of three hundred and sixty miles, they probably would go fifty on each side to the canal; hence, if I average the whole, such canal may be said to accommodate a country three hundred and sixty miles long, fifty miles wide; on which the tonnage must now be regulated.

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The man who resides twenty miles from Philadelphia, and seven from the canal, should he convey a ton of goods by land, it would be worth at least fifteen shillings, as it would employ a man and two horses two days*.

The carriage to the canal, seven miles in like proportion,	-	-	-	-	-	-	5
Carriage on the canal,	-	-	-	-	-	-	4
Total,							9

Thus the saving would be six shillings, and the tonnage should increase to a certain sum on the first hundred miles of canal, keeping much within the limits of land-carriage; then decrease as the boating increased, in order to draw the trade of the back country into the canal.

The expence of boating a ton twenty miles will be as follows: a man, boy, and horse, will convey forty tons twenty miles for ten shillings, which is three-pence per ton for twenty miles; but to allow contingencies, say four-pence per ton, for boating twenty miles; the tonnage and boating on the three hundred and sixty miles should then be regulated, perhaps, in the following order.

* The English reader, who may look over this chapter, may perhaps be surprised at stating the land-carriage of America so low. But as I do not know the average expence of that country, I estimate it low in order to give it every advantage, in a comparative view, with the canal. In England, it would cost at least one guinea, with all the advantage of good turnpike roads.

T 2

Miles.

Miles.	Tonnage.		Boating.		Amount.	
	s.	d.	s.	d.	s.	d.
20	4	0	0	4	4	4
40	8	0	0	8	8	8
60	12	0	1	0	13	0
80	16	0	1	4	17	4
* 100	20	0	1	8	21	8
120	19	8	2	0	21	8
140	19	4	2	4	21	8
160	19	0	2	8	21	8
180	18	8	3	0	21	8
200	18	4	3	4	21	8
220	18	0	3	8	21	8
240	17	8	4	0	21	8
260	17	4	4	4	21	8
280	17	0	4	8	21	8
300	16	8	5	0	21	8
320	16	4	5	4	21	8
340	16	0	5	8	21	8
† 360	15	8	6	0	21	8

By this system, the country at the extremity of three hundred and sixty miles, would deliver goods at Philadelphia for twenty-one shillings and eight-pence; which is the same as paid at the distance of one hundred miles; to which the land-carriage to the canal must be added. But as such a system would open a market to the remote country, every acre of ground within reach of the

* This being within the limits of land-carriage, the tonnage must now begin to decrease as the boating is increased.

† If the boats return without back-carriage, the expence of boating, which on the three hundred and sixty miles is six shillings, must be deducted from the tolls; and in proportion on the various parts of the canal.

canal

canal would become more valuable, and the carriage to the canal must be borne for some years. But as population increased, and the tonnage on the main line became productive, lateral branches would be cut from the canal, and thus further improve the country; the tonnage on such branches being proportioned as before stated, according to the distance from the city.

The carriage on such canal would consequently be immense; for, as I before stated, it would accommodate a country three hundred and sixty miles long, fifty miles wide, in the main, containing eighteen thousand square miles, or eleven million five hundred and twenty thousand acres. If, by further improvement, I allow that only every fiftieth acre will produce one ton of carriage per annum, the amount would be two hundred and thirty thousand four hundred tons; which appears, by averaging the preceding tonnage, would cost fifteen shillings per ton, in tolls to the canal, amounting to 172,800*l.* per annum, in order to construct further canal; a sum adequate to forming, perhaps eighty or one hundred miles per year: having arrived at such a length, it is evident canals would increase with astonishing rapidity, and produce conveniences, even beyond the limits of calculation; for it must be observed, and strictly adhered to, that by canals you may equalize the carriage of the near and remote country, as before exhibited by the mode of regulating the boating with the tonnage, in proportion to the extent; inasmuch as that a ton of goods may be carried three hundred and sixty miles for 1*l.* 1*s.* 8*d.* Yet, was I to extend the idea to a still more distant district, by reducing the tonnage as the boating increased, till the tolls were annihilated, and the boating amounted to 1*l.* 1*s.* 8*d.*; a ton of goods might be boated thirteen hundred miles for that sum; yet a ton could not be waggoned the same distance for less than 38*l.* 10*s.* so great is the disparity between land and water-carriage.

Hence

Hence it must be evident, that roads, however good, can never effectually assist the remote country, each mile is attended with a heavy expence on carriage, till penetrating so far, that the value of the produce is consumed in carriage; it terminates in a luxuriant wilderness, fable and uncultivated as the interior of Africa. But by canals, the conveyance may be so easy, that they may penetrate the most remote districts, draw down the produce to the ports of trade, and bear up the various conveniences of life; thus each man may exchange his surplus labour for the necessities or luxuries which he may require; hence his faculties will be put into action, cultivation will flourish, and enjoyment be more equally diffused; canals will pass through every vale, meander round each hill, and bind the whole country in the bonds of social intercourse; hence population will be increased, each acre of land will become valuable, industry will be stimulated, and the nation, gaining strength, will rise to unparalleled importance, by virtue of so powerful an ally as canals.

Having exhibited the immense disparity between canals and roads, with the mode of extending canals in every direction, by appropriating the tolls; it is evident, that such a system will produce infinite navigation. But the mode of constructing them must be maturely considered; and in this, two things must be scrupulously adhered to.

First, that canals may truly benefit a country, it is necessary the passage should be performed with equal ease each way. Second, that the nearest course should be taken to the principal points of the country; and for both these reasons, the beds of the rivers, beyond tide, must almost universally be for-

forfaken*; because torrents, in time of rain, which is extremely injurious to the works of art, with the shoals in dry seasons, together with the current ever standing one way, will very frequently interrupt free intercourse, and render fresh-water river navigations precarious.

The rivers, creeks, and rivulets, which are numerous in all parts, must be considered as the feeders of canals; and, in this respect, having an abundance of water, America is very fortunate; land is also cheap and timber plenty, so that the great expence of an American canal would be labour.

Therefore, as it is the channels of art, which can only effectually assist the country, I have constantly endeavoured to find a system which might pass by the straightest line to a given point; hence you will observe the mode of mounting hills, crossing valleys, rivers, and defiles, by the various machines; which, I hope, will display an easy means of extending water communications through a great continent, and bear the mind to those days, when a well-directed oeconomy in manual labour will give enlightened and rational enjoyment to many millions of inhabitants: hoping, that this important subject will make a part of the deliberation of a wise Legislature,

I remain, with all possible Respect,

Yours sincerely,

ROBERT FULTON.

London, March, 1796.

* By forsaking the beds of the rivers I mean, that they should not compose or make a Principle part of a leading canal; yet, however numerous canals may be, it will frequently happen that some miles of a river, will afford easy navigation in particular seasons, and probably touch the leading canals into which the goods, or perhaps boats, may be transferred from the river; for small boats will live on the American rivers in particular parts and seasons, of which there are innumerable instances by the batteaus and even canoes.

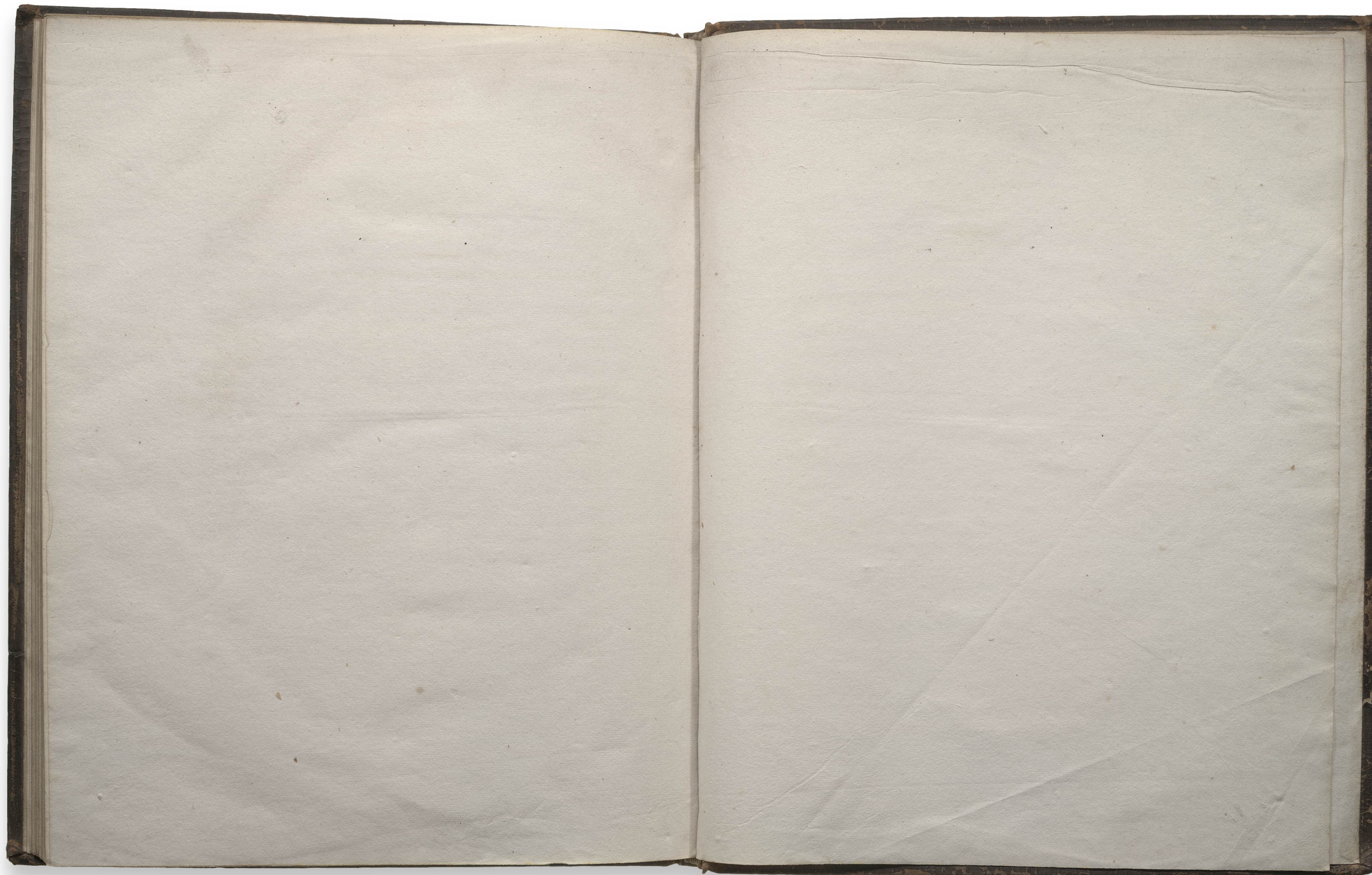
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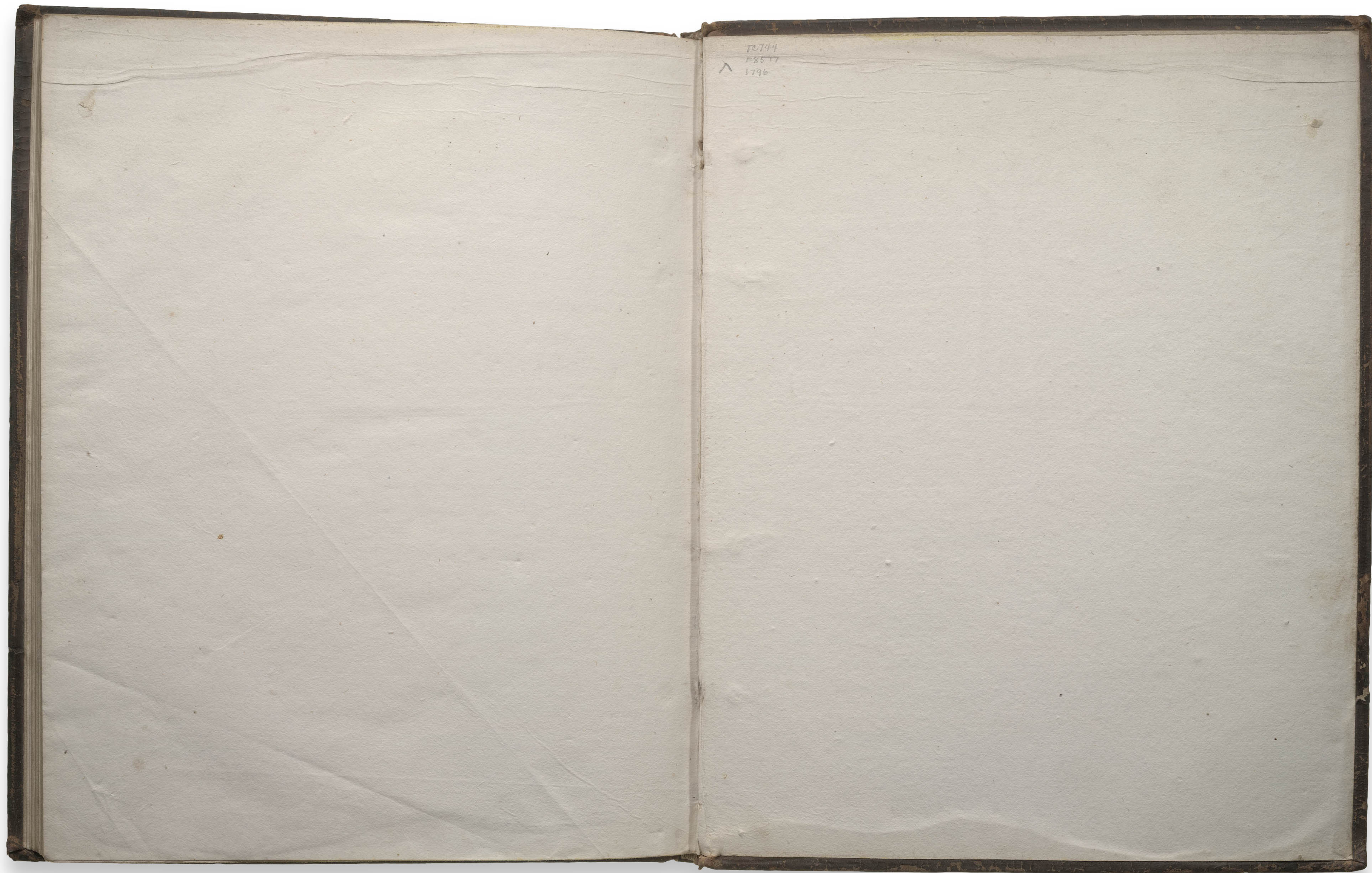
IN conducting a line of canal through a mountainous country, it may, in many instances, be extremely difficult to supply the top level with water to work the machinery; yet the country may produce sufficient at the next lower level; for instance, at one or two hundred feet below the top pond of canal.

In such case, if the ground is sloping, so as to admit of a discharge from the bottom of the tub-pit, *or even a water wheel*, the machinery exhibited by the preceding Engravings may be placed at the bottom of the plane, and receive motion from the water of the lower level; by which the boats may be passed to and from the summit with the same facility as if the machinery was on top of the plane, and thus the water of the summit level will be preserved: which exhibits another important advantage over lock canals.

The whole of the apparatus will also equally apply, whether there are wheels to the boats or rollers to the plane.

F I N I S.





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